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THE WARFARE OF SCIENCE.

By ANDREW D. WHITE, LL. D.,
PRESIDENT OF CORNELL UNIVERSITY.

I.

I PURPOSE to present an outline of the great, sacred struggle for the liberty of science—a struggle which has lasted for so many centuries, and which yet continues. A hard contest it has been; a war waged longer, with battles fiercer, with sieges more persistent, with strategy more shrewd than in any of the comparatively petty warfares of Cæsar or Napoleon or Moltke.

I shall ask you to go with me through some of the most protracted sieges, and over some of the hardest-fought battle-fields of this war. We will look well at the combatants; we will listen to the battle-cries; we will note the strategy of leaders, the cut and thrust of champions, the weight of missiles, the temper of weapons.

My thesis, which, by an historical study of this warfare, I expect to develop, is the following: *In all modern history, interference with science in the supposed interest of religion, no matter how conscientious such interference may have been, has resulted in the direst evils both to religion and to science, and invariably. And, on the other hand, all untrammeled scientific investigation, no matter how dangerous to religion some of its stages may have seemed, for the time, to be, has invariably resulted in the highest good of religion and of science.* I say "invariably." I mean exactly that. It is a rule to which history shows not one exception

It would seem, logically, that this statement cannot be gainsaid. God's truths must agree, whether discovered by looking within upon the soul, or without upon the world. A truth written upon the human heart to-day, in its full play of emotions or passions, cannot be

[1] In its earlier form this address was given as a Phi Beta Kappa oration at Brown University, and as a lecture at New York, Boston, New Haven, Ann Arbor, and elsewhere.

at any real variance even with a truth written upon a fossil whose poor life ebbed forth millions of years ago.

This being so, it would also seem a truth irrefragable, that the search of each of these kinds of truth must be followed out on its own lines, by its own methods, to its own results, without any interference from investigators on other lines, or by other methods. And it would also seem logical to work on in absolute confidence that whatever, at any moment, may seem to be the relative positions of the two different bands of workers, they must at last come together, for Truth is one.

But logic is not history. History is full of interferences which have cost the earth dear. Strangest of all, some of the direst of them have been made by the best of men, actuated by the purest motives, and seeking the noblest results. These interferences, and the struggle against them, make up the warfare of science.

One statement more, to clear the ground. You will not understand me at all to say that religion has done nothing for science. It has done much for it. The work of Christianity, despite the clamps which men have riveted about it, has been mighty indeed. Through these two thousand years, it has undermined servitude, mitigated tyranny, given hope to the hopeless, comfort to the afflicted, light to the blind, bread to the starving, joy to the dying, and this work continues. And its work for science, too, has been great. It has fostered science often. Nay, it has nourished that feeling of self-sacrifice for human good, which has nerved some of the bravest men for these battles.

Unfortunately, some good men started centuries ago with the idea that purely scientific investigation is unsafe—that theology must intervene. So began this great modern war.

The first typical battle-field to which I would refer is that of Geography—the simplest elementary doctrine of the earth's shape and surface.

Among the legacies of thought left by the ancient world to the modern, were certain ideas of the rotundity of the earth. These ideas were vague; they were mixed with absurdities; but they were *germ ideas*, and, after the barbarian storm which ushered in the modern world had begun to clear away, these germ ideas began to bud and bloom in the minds of a few thinking men, and these men hazarded the suggestion that the earth is round—is a globe.[1]

The greatest and most earnest men of the time took fright at once. To them, the idea of the earth's rotundity seemed fraught with dan-

[1] Most fruitful among these were those given by Plato in the "Timæus." *See*, also, Grote on Plato's doctrine of the rotundity of the earth. Also Sir G. C. Lewis's "Astronomy of the Ancients," London, 1862, chap. iii., sec. i. and note. Cicero's mention of the antipodes and reference to the passage in the "Timæus" are even more remarkable than the original, in that they much more clearly foreshadow the modern doctrine. *See* "Academic Questions," ii., xxix. Also, "Tusc. Quest.," i., xxviii., and v., xxiv.

gers to Scripture: by which, of course, they meant *their interpretation* of Scripture.

Among the first who took up arms against the new thinkers was Eusebius. He endeavored to turn off these ideas by bringing science into contempt. He endeavored to make the innovators understand that he and the fathers of the Church despised all such inquiries. Speaking of the innovations in physical science, he said: "It is not through ignorance of the things admired by them, but through contempt of their useless labor, that we think little of these matters, turning our souls to better things."[1]

Lactantius asserted the ideas of those studying astronomy to be "mad and senseless."[2]

But the attempt to "flank" the little phalanx of thinkers did not succeed, of course. Even such men as Lactantius and Eusebius cannot pooh-pooh down a new scientific idea. The little band of thinkers went on, and the doctrine of the rotundity of the earth naturally led to the consideration of the tenants of the earth's surface, and another germ idea was[3] warmed into life—the idea of the existence of the antipodes, the idea of the existence of countries and men on the hemisphere opposite to ours.

At this the war spirit waxed hot. Those great and good men determined to fight. To all of them such doctrines seemed dangerous; to most of them they seemed damnable. St. Basil and St. Ambrose[4] were tolerant enough to allow that a man might be saved who believed the earth to be round, and inhabited on its opposite sides; but the great majority of the Fathers of the Church utterly denied the possibility of salvation to such misbelievers.

Lactantius asks ". . . Is there any one so senseless as to believe that there are men whose footsteps are higher than their heads?—that the crops and trees grow downward?—that the rains and snow and

[1] *See* Eusebius, "Præp. Ev.," xv., 61.

[2] *See* Lactantius, "Inst.," l., iii., chap. 3. Also, citations in Whewell, "Hist. Induct. Sciences," Lond., 1857, vol. i., p. 194. To understand the embarrassment thus caused to scientific men at a later period, *see* "Letter of Agricola to Joachimus Vadianus" in 1514. Agricola asks Vadianus to give his views regarding the antipodes, saying that he himself does not know what to do, between the Fathers on one side and learned men of modern times on the other. On the other hand, for the embarrassment caused to the Church by this mistaken zeal of the Fathers, *see* Kepler's references and Fromund's replies; also De Morgan, "Paradoxes," p. 58. Kepler appears to have taken great delight in throwing the views of Lactantius into the teeth of his adversaries.

[3] "Another germ idea," etc. *See* Plato, "Timæus," 62 C., Jowett's translation, N. Y. ed. Also "Phædo," pp. 449, *et seq.* Also Cicero, "Academic Quest.," and "Tusc. Disput.," *ubi supra.* For citations and summaries, *see* Whewell, "Hist. Induct. Sciences," vol. i., p. 189, and St. Martin, "Hist. de la Géog.," Paris, 1873, p. 96. Also Leopardi, "Saggio sopra gli errori popolari degli antichi," Firenze, 1851, chap. xii., p. 184, *et seq.*

[4] For opinion of Basil, Ambrose and others, *see* Lecky, "Hist. of Rationalism in Europe," New York, 1872, vol. i., p. 279, note. Also Letronne, in *Revue des Deux Mondes*, March, 1834.

hail fall upward toward the earth? . . . But if you inquire from those who defend these marvelous fictions, why all things do not fall into that lower part of the heaven, they reply that such is the nature of things, that heavy bodies are borne toward the middle, like the spokes of a wheel; while light bodies, such as clouds, smoke, and fire, tend from the centre toward the heavens on all sides. Now, I am at loss what to say of those who, when they have once erred, steadily persevere in their folly, and defend one vain thing by another."

Augustine seems inclined to yield a little in regard to the rotundity of the earth, but he fights the idea that men exist on the other side of the earth, saying that "Scripture speaks of no such descendants of Adam."

But this did not avail to check the idea. What may be called the flank movement, as represented by Eusebius, had failed. The direct battle given by Lactantius, Augustine, and others, had failed. In the sixth century, therefore, the opponents of the new ideas built a great fortress and retired into that. It was well built and well braced. It was nothing less than a complete theory of the world, based upon the literal interpretation of texts of Scripture, and its author was Cosmas Indicopleustes.[1]

According to Cosmas, the earth is a parallelogram, flat, and surrounded by four great seas. At the outer edges of these seas rise immense walls closing in the whole structure. These walls support the vault of the heavens, whose edges are cemented to the walls; walls and vault shut in the earth and all the heavenly bodies. The whole of this theologic, scientific fortress was built most carefully, and, as was then thought, most scripturally.

Starting with the expression, *Το ἅγιον κοσμικόν*, applied in the ninth chapter of Hebrews to the tabernacle in the desert, he insists, with other interpreters of his time, that it gives a key to the whole construction of the world. The universe is, therefore, made on the plan of the Jewish Tabernacle—box-like and oblong.

Coming to details, he quotes those grand words of Isaiah,[2] "It is he that sitteth upon the circle of the earth, . . . that stretcheth out the heavens like a curtain, and spreadeth them out like a tent to dwell in," and the passage in Job,[3] which speaks of the "pillars of heaven." He turns all that splendid and precious poetry into a prosaic statement, and gathers therefrom, as he thinks, treasures for science.

This vast box is then divided into two compartments, one above the other. In the first of these, men live and stars move; and it ex-

[1] For Lactantius, *see* "Instit.," iii., 24, translation in Ante-Nicene Library; also, citations in Whewell, i., 196, and in St. Martin, "Histoire de la Géographie," pp. 216, 217. For St. Augustine's opinion, *see* the "Civ. D.," xvi., 9, where this great Father of the Church shows that the existence of the antipodes "*nulla ratione credendum est.*" Also, citations in Buckle's "Posthumous Works," vol. ii., p. 645.

[2] Isaiah xl. 22. [3] Job xxvi. 11.

tends up to the first solid vault or firmament, where live the angels, a main part of whose business it is to push and pull the sun and planets to and fro. Next he takes the text, "Let there be a firmament in the midst of the waters, and let it divide the waters from the waters," and other texts from Genesis.[1] To these he adds the texts from the Psalms, "Praise him ye heaven of heavens, and ye waters that be above the heavens,"[2] casts that outburst of poetry into his crucible with the other texts, and, after subjecting them to sundry peculiar processes, brings out the theory that over this first vault is a vast cistern containing the waters. He then takes the expression in Genesis regarding the "windows of heaven,"[3] and establishes a doctrine regarding the regulation of the rain, which is afterward supplemented by the doctrine that the angels not only push and pull the heavenly bodies, to light the earth, but also open and close the windows of heaven to water it.

To find the character of the surface of the earth, Cosmas studies the table of shew-bread in the Tabernacle. The dimensions of that table prove to him that the earth is flat and twice as long as broad. The four corners of the table symbolize the four seasons.

To account for the movement of the sun, Cosmas suggests that at the north of the earth is a great mountain, and that, at night, the sun is carried behind this. But some of the commentators ventured to express a doubt here. They thought that the sun was pushed into a great pit at night, and was pulled out in the morning.

Nothing can be more touching in its simplicity than Cosmas's closing of his great argument. He bursts forth in raptures, declaring that Moses, the prophets, evangelists, and apostles, agree to the truth of his doctrine.[4]

Such was the fortress built against human science in the sixth century, by Cosmas; and it stood. The innovators attacked it in vain. The greatest minds in the Church devoted themselves to buttressing it with new texts, and throwing out new outworks of theologic reasoning. It stood firm for two hundred years, when a bishop—Virgilius of Salzburg—asserts his belief in the existence of the antipodes.

It happened that there then stood in Germany, in the first years of the eighth century, one of the greatest and noblest of men—St. Boniface. His learning was of the best then known; in labors he was a worthy successor to the apostles; his genius for Christian work made

[1] Genesis i. 6. [2] Psalm cxlviii. 4. [3] Genesis vii. 11.

[4] *See* Montfaucon, "Collectio Nova Patrum," Paris, 1706, vol. ii., p. 188; also, pp. 298, 299. The text is illustrated with engravings showing walls and solid vault (firmament), with the whole apparatus of "fountains of the great deep," "windows of heaven," angels, and the mountain behind which the sun is drawn. For an imperfect reduction of one of them, *see* article "Maps," in Knight's "Dictionary of Mechanics," New York, 1875. For still another theory, very droll, and thought out on similar principles, *see* Mungo Park, cited in De Morgan, "Paradoxes," 309. For Cosmas's joyful summing up, *see* Montfaucon, "Collectio Nova Patrum," vol. ii., p. 255.

him, unwillingly, Primate of Germany; his devotion afterward led him, willingly, to martyrdom. There sat, too, at that time, on the papal throne, a great Christian statesman—Pope Zachary. Boniface immediately declares against the revival of such a terrible heresy as the existence of the antipodes. He declares that it amounts to the declaration that there are men on the earth beyond the reach of the means of salvation; he attacks Virgilius; he calls on Zachary for aid; effective measures are taken, and we hear no more of Virgilius or his doctrine.

Six hundred years pass away, and in the fourteenth century two men publicly assert the doctrine. The first of these, Peter of Abano, escapes punishment by natural death; the second, known as Cecco d'Ascoli, a man of seventy years, is burned alive. Nor was that all the punishment: that great painter, Orcagna, whose terrible works you may see on the walls of the Campo Santo at Pisa, immortalized Cecco by representing him in the flames of hell.[1]

Still the idea lived and moved, and a hundred years later we find the theologian Tostatus protesting against the doctrine of the antipodes as "unsafe." He has invented a new missile—the following syllogism: "The apostles were commanded to go into all the world, and to preach the gospel to every creature. They did not go to any such part of the world as the antipodes, they did not preach to any creatures there: *ergo*, no antipodes exist." This is just before the time of Columbus.

Columbus is the next warrior. The world has heard of his battles: how the Bishop of Ceuta worsted him in Portugal; how at the Junta of Salamanca the theologians overwhelmed him with quotations from the Psalms, from St. Paul, and from St. Augustine.[2]

But in 1519 Science gains a crushing victory. Magalhaens makes his famous voyages. He has proved the earth to be round; for his great expedition has circumnavigated it. He proves the doctrine of the antipodes, for he sees the men of the antipodes.[3] But even this

[1] Virgil of Salzburg. *See* Neander's "History of the Christian Church," Torrey's translation, vol. iii., p. 63. Since Bayle, there has been much loose writing about Virgil's case. *See* Whewell, p. 197; but for best choice of authorities and most careful winnowing out of conclusions, *see* De Morgan, pp. 24–26. For very full notes as to pagan and Christian advocates of doctrine of rotundity of the earth and of antipodes, and for extract from Zachary's letter, *see* Migne, "Patrologia," vol. vi., p. 426, and vol. xli., p. 487. For Peter of Abano, or Apono, as he is often called, *see* Tiraboschi; also Ginguené, vol. ii., p. 293. Also Naudé, "Histoire des grands hommes accusés de Magie." For Cecco d'Ascoli, *see* Montucla, "Histoire des Mathématiques," i., 528; also, Daunou, "Études Historiques," vol. vi., p. 320. Concerning Orcagna's representation of Cecco in flames of hell, *see* Renan, "Averroès et l'Averroisme," Paris, 1867, p. 328.

[2] For Columbus before the Junta of Salamanca, *see* Irving's "Columbus," Murray's, edition, vol. ii., pp. 405–410. Figuier, "Savants du Moyen Age," etc., vol. ii., p. 394, *et seq.* Also Humboldt, "Histoire de la Géographie du Nouveau Continent."

[3] For effect of Magalhaens's voyages, and the reluctance to yield to proof, *see* Henri Martin, "Histoire de France," vol. xiv., p. 395; St. Martin's "Histoire de la Géog.,"

does not end the war. Many earnest and good men oppose the doctrine for two hundred years longer. Then the French astronomers make their measurements of degrees in equatorial and polar regions and add to other proofs that of the lengthened pendulum. When this was done, when the deductions of science were seen to be established by the simple test of measurement, beautifully, perfectly, then and then only this war of twelve centuries ended.[1]

And now what was the result of this war? The efforts of Eusebius and Lactantius to deaden scientific thought; the efforts of Augustine to combat it; the efforts of Cosmas to stop it by dogmatism; the efforts of Boniface, and Zachary, and others to stop it by force, conscientious as they all were, had resulted in what? Simply in forcing into many noble minds this most unfortunate conviction, that Science and Religion are enemies; simply in driving away from religion hosts of the best men in all those centuries. The result was wholly bad. No optimism can change that verdict.

On the other hand, what was gained by the warriors of science for religion? Simply, a far more ennobling conception of the world, and a far truer conception of Him who made and who sustains it.

Which is the more consistent with a great, true religion—the cosmography of Cosmas, or that of Isaac Newton? Which presents the nobler food for religious thought—the diatribes of Lactantius, or the astronomical discourses of Thomas Chalmers?

The next great battle was fought on a question relating to the *position of the earth among the heavenly bodies.* On one side, the great body of conscientious religious men planted themselves firmly on the geocentric doctrine—the doctrine that the earth is the centre, and that the sun and planets revolve about it. The doctrine was old, and of the highest respectability.[2] The very name, Ptolemaic theory, carried weight. It had been elaborated until it accounted well for the phenomena. Exact textual interpreters of Scripture cherished it, for it agreed with the letter of the sacred text.[3]

Still the germs of the heliocentric theory[4] had been planted long before, and well planted; it had seemed ready even to bloom forth

p. 369; Peschel, "Geschichte des Zeitalters der Entdeckungen," concluding chapters; and for an admirable summary, Draper, "Hist. Int. Dev. of Europe," pp. 451–453.

[1] For general statement as to supplementary proof by measurement of degrees, and by pendulum, *see* Somerville, "Phys. Geog.," chapter i., § 6, note. Also Humboldt, "Cosmos," vol. ii., p. 736, and v., pp. 16, 32. Also, Montucla, iv., 138.

[2] "Respectability of Geocentric Theory, Plato's Authority for it," etc., *see* Grote's "Plato," vol. iii., p. 257. Also, Sir G. C. Lewis, "Astronomy of the Ancients," chap. iii., sec. i., for a very thoughtful statement of Plato's view, and differing from ancient statements. For plausible elaboration of it, *see* Fromundus, "Anti-Aristarchus," Antwerp, 1631. Also Melanchthon "Initia Doctrinæ Physicæ."

[3] For supposed agreement of Scripture with Ptolemaic theory, *see* Fromundus, *passim*, Melanchthon, and a host of other writers.

[4] For "Germs of Heliocentric Theory planted long before," etc., *see* Sir G. C. Lewis; also, Draper, "Intellectual Development of Europe," p. 512. For germs among thinkers

from the mind of Cardinal de Cusa; but the chill of dogmatism was still over the earth, and up to the beginning of the sixteenth century there had come to this great truth neither bloom nor fruitage.[1]

Quietly, however, the soil was receiving enrichment, and the air warmth. The processes of mathematics were constantly improved, the heavenly bodies were steadily though silently observed, and at length appeared, afar off from the centres of thought, on the borders of Poland, a plain, simple-minded scholar, who first fairly uttered to the world the truth, now so commonplace, then so astounding, that the sun and planets do not revolve about the earth, but that the earth and planets revolve about the sun, and that man was Nicholas Kopernik.[2]

Kopernik had been a professor at Rome, but, as this truth grew within him, he seemed to feel that at Rome he was no longer safe.[3]

of India, *see* Whewell, vol. i., p. 277. Also, Whitney, "Oriental and Linguistic Studies," New York, 1874. "Essay on the Lunar Zodiac," p. 345.

[1] For general statement of De Cusa's work, *see* Draper, "Intellectual Development of Europe," p. 512. For skillful use of De Cusa's view in order to mitigate censure upon the Church for its treatment of Copernicus's discovery, *see* an article in the *Catholic World*, for January, 1869. For a very exact statement, in a spirit of judicial fairness, *see* Whewell, "History of the Inductive Sciences," p. 275 and pp. 379, 380. In the latter, Whewell cites the exact words of De Cusa in the "De Docta Ignorantia," and sums up in these words: "This train of thought might be a preparation for the reception of the Copernican system; but it is very different from the doctrine that the sun is the centre of the planetary system." In the previous passage, Whewell says that De Cusa "propounded the doctrine of the motion of the earth, more, however, as a paradox than as a reality. We cannot consider this as any distinct anticipation of a profound and consistent view of the truth."

[2] For improvement of mathematical processes, *see* Draper, "Intellectual Development of Europe," 513. In looking at this and other admirable summaries, one feels that Prof. Tyndall was not altogether right in lamenting, in his farewell address at New York, that Dr. Draper has devoted so much of his time to historical studies.

[3] Copernicus's danger at Rome. The *Catholic World* for January, 1869, cites a recent speech of the Archbishop of Mechlin before the University of Louvain, to the effect that Copernicus defended his theory, at Rome, in 1500, before two thousand scholars; also, that another professor taught the system in 1528, and was made Apostolic Notary by Clement VIII. All this, even if the doctrines taught were identical with those of Copernicus, as finally developed, which idea Whewell seems utterly to disprove, avails nothing against the overwhelming testimony that Copernicus felt himself in danger—testimony which the after-history of the Copernican theory renders invincible. The very title of Fromundus's book, already cited, published within a few miles of the archbishop's own cathedral, and sanctioned expressly by the theological Faculty of that same University of Louvain in 1630, utterly refutes the archbishop's idea that the Church was inclined to treat Copernicus kindly. The title is as follows:

"Anti-Aristarchus | Sive | Orbis-Terræ | Immobilis | In quo decretum S. Congregationis S. R. E. | Cardinalium | IↃC. XVI adversus Pytha | gorico-Copernicanos editum defenditur | Antwerpiæ MDCXXXI."

L'Epinois, "Galilée," Paris, 1867, lays stress, p. 14, on the broaching of the doctrine by De Cusa, in 1435, and by Widmanstadt, in 1533, and their kind treatment by Eugenius IV. and Clement VII., but this is absolutely worthless in denying the papal policy afterward. Lange, "Geschichte des Materialismus," vol. i., pp. 217, 218, while

To publish this thought was dangerous indeed, and for more than thirty years it lay slumbering in the minds of Kopernik and the friends to whom he had privately intrusted it.

At last he prepares his great work on the "Revolution of the Heavenly Bodies," and dedicates it to the pope himself. He next seeks a place of publication. He dares not send it to Rome, for there are the rulers of the older Church ready to seize it. He dares not send it to Wittenberg, for there are the leaders of Protestantism no less hostile. He therefore intrusts it to Osiander, of Nuremberg.[1]

But, at the last moment, the courage of Osiander failed him. He dared not launch the new thought boldly. He writes a groveling preface; endeavors to excuse Kopernik for his novel idea. He inserts the apologetic lie that Kopernik propounds the doctrine of the movement of the earth, not as a *fact*, but as an *hypothesis*. He declares that it is lawful for an astronomer to indulge his *imagination*, and that this is what Kopernik has done.

Thus was the greatest and most ennobling, perhaps, of scientific truths—a truth not less ennobling to religion than to science—forced, in coming into the world, to sneak and crawl.[2]

On the 24th of May, 1543, the newly-printed book first arrived at the house of Kopernik. It was put into his hands; but he was on his death-bed. A few hours later he was beyond the reach of those mistaken, conscientious men, whose consciences would have blotted his reputation, and perhaps have destroyed his life.

Yet not wholly beyond their reach. Even death could not be trusted to shield him. There seems to have been fear of vengeance upon his corpse, for on his tombstone was placed no record of his life-long labors, no mention of his great discovery. There were graven upon it affecting words, which may be thus simply trans-

admitting that De Cusa and Widmanstadt sustained this idea and received honors from their respective popes, shows that, when the Church gave it serious consideration, it was condemned. There is nothing in this view unreasonable. It would be a parallel case to that of Leo X., at first inclined toward Luther and the others, in their "squabbles with the begging friars," and afterward forced to oppose them.

[1] For dangers at Wittenberg, *see* Lange, "Geschichte des Materialismus," vol. i., p. 217.

[2] Osiander, in a letter to Copernicus, dated April 20, 1541, had endeavored to reconcile him to such a procedure, and ends by saying, "Sic enim placidiores reddideris peripatheticos et theologos quos contradicturos metuis." *See* Apologia Tychonis in "Kepleri Opera Omnia," Frisch's edition, vol. i., p. 246. Kepler holds Osiander entirely responsible for this preface. Bertrand, in his "Fondateurs de l'Astronomie Moderne," gives its text, and thinks it possible that Copernicus may have yielded "in pure condescension toward his disciple." But this idea is utterly at variance with expressions in Copernicus's own dedicatory letter to the pope, which follows the preface. For a good summary of the argument, *see* Figuier, "Savants de la Renaissance," pp. 378, 379. *See* also, citation from Gassendi's life of Copernicus, in Flammarion, "Vie de Copernic," p. 124. Mr. John Fiske, accurate as he usually is, in his recent "Outlines of Cosmic Philosophy," appears to have fallen into the error of supposing that Copernicus, and not Osiander, is responsible for the preface.

lated: "I ask not the grace accorded to Paul, not that given to Peter; give me only the favor which thou didst show to the thief on the cross." Not till thirty years after did a friend dare write on his tombstone a memorial of his discovery.[1]

The book was taken in hand at once by the proper authorities. It was solemnly condemned: to read it was to risk damnation; and the world accepted the decree.[2]

Doubtless many will at once exclaim against the Roman Catholic Church for this. Justice compels me to say that the founders of Protestantism were no less zealous against the new scientific doctrine. Said Martin Luther: "People gave ear to an upstart astrologer, who strove to show that the earth revolves, not the heavens or the firmament, the sun and the moon. Whoever wishes to appear clever must devise some new system which of all systems is, of course, the very best. This fool wishes to reverse the entire science of astronomy. But Sacred Scripture tells us that Joshua commanded the sun to stand still, and not the earth."

Melanchthon, mild as he was, was not behind Luther in condemning Kopernik. In his treatise, "Initia Doctrinæ Physicæ," he says: "The eyes are witnesses that the heavens revolve in the space of twenty-four hours. But certain men, either from the love of novelty, or to make a display of ingenuity, have concluded that the earth moves; and they maintain that neither the eighth sphere nor the sun revolves. . . . Now, it is a want of honesty and decency to assert such notions publicly, and the example is pernicious. It is the part of a good mind to accept the truth as revealed by God, and to acquiesce in it." Melanchthon then cites passages from the Psalms and from Ecclesiastes which he declares assert positively and clearly that the earth stands fast, and that the sun moves around it, and adds eight other proofs of his proposition that "the earth can be nowhere, if not in the centre of the universe."[3]

[1] Figuier, "Savants de la Renaissance," p. 380. Also, Flammarion, "Vie de Copernic," p. 190.

[2] The "proper authorities" in this case were the "Congregation of the Index," or cardinals having charge of the "Index Librorum Prohibitorum." Recent desperate attempts to fasten the responsibility on them as individuals seem ridiculous in view of the simple fact that their work is sanctioned by the highest Church authority, and required to be universally accepted by the Church. Three of four editions of the "Index" in my own possession declare on their title-pages that they are issued by order of the pontiff of the period, and each is prefaced by a special papal bull or letter. See specially Index of 1664, issued under order of Alexander VII., and that of 1761, under Benedict XIV. Copernicus's work was prohibited in the Index "*donec corrigatur.*" Kepler said that it ought to be worded "*donec explicetur.*" *See* Bertrand, "Fondateurs de l'Astronomie Moderne," p. 57. De Morgan, pp. 57–60, gives the corrections required by the Index of 1620. Their main aim seems to be to reduce Copernicus to the groveling level of Osiander, making of his discovery a mere hypothesis; but occasionally they require a virtual giving up of the whole Copernican doctrine, e. g., "correction" insisted upon for cap. 8, p. 6.

[3] *See* Luther's "Table Talk." Also, Melanchthon's "Initia Doctrinæ Physicæ." This

And Protestant people are not a whit behind Catholic in following out these teachings. The people of Elbing made themselves merry over a farce in which Kopernik was the main object of ridicule. The people of Nuremberg, a great Protestant centre, caused a medal to be struck, with inscriptions ridiculing the philosopher and his theory.[1]

Then was tried one piece of strategy very common formerly in battles between theologians themselves. It consists in loud shoutings that the doctrine attacked is old, outworn, and already refuted—that various distinguished gentlemen have proved it false—that it is not a living truth, but a detected lie—that, if the world listens to it, that is simply because the world is ignorant. This strategy was brought to bear on Copernicus. It was shown that his doctrine was simply a revival of the Pythagorean notion, which had been thoroughly exploded. Fromundus, in his title-page and throughout his book, delights in referring to the doctrine of the revolution of the planets around the sun, as "that Pythagorean notion." This mode of warfare was imitated by the lesser opponents, and produced, for some time, considerable effect.[2]

But the new truth could neither be laughed down nor forced down. Many minds had received it; only one tongue dared utter it. This new warrior was that strange mortal, Giordano Bruno. He was hunted from land to land, until, at last, he turns on his pursuers with fearful invectives. For this he is imprisoned six years, then burned alive and his ashes scattered to the winds. Still the new truth lived on; it could not be killed. Within ten years after the martyrdom of Bruno,[3] after a world of troubles and persecutions, the

treatise is cited by the *Catholic World*, September, 1870. The correct title is as given above. It will be found in the "Corpus Reformatorum," ed. Bretschneider: Halle, 1846. (For the above passage *see* vol. xiii., pp. 216, 217.) Also, Lange, "Geschichte des Materialismus," vol. i., p. 217. Also, Prowe, "Ueber die Abhängigkeit des Copernicus," Thorn, 1865, p. 4. Also, note, pp. 5 and 6, where text is given in full.

[1] For treatment of Copernican ideas by the people, *see Catholic World*, as above. Fromundus, cited above, heads his sixth chapter as follows, "Scriptura Sacra Oppugnat Copernicanos," and cites from the Psalms the passage speaking of the sun which "cometh forth as a bridegroom from his chamber;" and also from Ecclesiastes, "Terra in Aeternum Stat." "Anti-Aristarchus," p. 29. Some of his titles also show his style in philosophical argument, e. g., "The wind would constantly blow from the east; we should, with great difficulty, hear sounds against such a wind" (chapter xi.); "Buildings, and the earth itself, would fly off with such a rapid motion" (chapter x.). For another of Fromundus's arguments, showing, both from theology and mathematics (with suitably-mixed theology), that the earth must be in the centre of the universe, *see* Quetelet, "Histoire des Sciences Mathématiques et Physiques," p. 170, Bruxelles, 1864.

[2] *See* title-page of Fromundus's work cited in note at bottom of p. 392; also, Melanchthon, *ubi supra*.

[3] *See* Bartholmès, "Vie de Jordano Bruno," Paris, 1846, vol. i., pp. 121 and pp. 212, *et seq.* Also Berti, "Vita di Giordano Bruno," Firenze, 1868, chapter xvi. Also Whewell, i., 294, 295. That Whewell is somewhat hasty in attributing Bruno's punishment entirely to the "Spaccio della Bestia Trionfante" will be evident, in spite of Montcula, to any one who reads the account of the persecution in Bartholmès or Berti; and, even if

truth of the doctrine of Kopernik was established by the telescope of Galileo.[1]

Herein was fulfilled one of the most touching of prophecies. Years before, the enemies of Kopernik had said to him, "If your doctrines were true, Venus would show phases like the moon." Kopernik answered: "You are right. I know not what to say; but God is good, and will in time find an answer to this objection."[2] The God-given answer came when the rude telescope of Galileo showed the phases of Venus.

On this new champion, Galileo, the attack was tremendous. The supporters of what was called "sound learning" declared his discoveries deceptions, and his announcements blasphemy. Semi-scientific professors, endeavoring to curry favor with the Church, attacked him with sham science; earnest preachers attacked him with perverted Scripture![3]

The principal weapons in the combat are worth examining. They are very easily examined. You may pick them up on any of the battle-fields of science; but on that field they were used with more effect than on almost any other. These weapons are two epithets: "Infidel" and "Atheist."

The battle-fields of science are thickly strewn with these. They have been used against almost every man who has ever done anything new for his fellow-men. The list of those who have been denounced as infidel and atheist includes almost all great men of science —general scholars, inventors, philanthropists. The deepest Christian life, the most noble Christian character have not availed to shield combatants. Christians like Isaac Newton and Pascal and John Locke and John Milton, and even Howard and Fénelon, have had these weapons hurled against them. Of all proofs of the existence of a God, those of Descartes have been wrought most thoroughly into the minds of modern men; and yet the Protestant theologians of Holland sought to bring him to torture and to death by the charge of atheism.[4]

Whewell be right, the "Spaccio" would never have been written, but for Bruno's indignation at ecclesiastical oppression. *See* Tiraboschi, vol. xi., p. 435.

[1] Delambre, "Histoire de l'Astronomie moderne," discours préliminaire, p. xiv. Also Laplace, "Système du Monde," vol. i., p. 326, and, for more careful statement, "Kepleri Opera Omnia," edit. Frisch, tom. ii., p. 464.

[2] Cantu, "Histoire Universelle," vol. xv., p 473.

[3] A very curious example of this sham science is seen in the argument, frequently used at the time, that, if the earth really moved, a stone falling from a height would fall back of the point immediately below its point of starting. This is used by Fromundus with great effect. It appears never to have occurred to him to test the matter by dropping a stone from the topmast of a ship. But the most beautiful thing of all is that Benzenburg has experimentally demonstrated just such an aberration in falling bodies as is mathematically required by the diurnal motion of the earth. *See* Jevons, "Principles of Science," vol. i., p. 453, and ii., pp. 310, 311.

[4] For curious exemplification of the way in which these weapons have been hurled, *see* lists of persons charged with "infidelity" and "atheism," in "Le Dictionnaire des Athées." Paris, An. viii. Also Lecky, "History of Rationalism," vol. ii., p. 50.

These can hardly be classed with civilized weapons. They are burning arrows. They set fire to great masses of popular prejudices; smoke rises to obscure the real questions, fire bursts forth at times to destroy the attacked party. They are poisoned weapons. They go to the hearts of loving women, they alienate dear children. They injure the man after life is ended, for they leave poisoned wounds in the hearts of those who loved him best—fears for his eternal happiness—dread of the divine displeasure.

Of course, in these days, these weapons, though often effective in disturbing good men, and in scaring good women, are somewhat blunted. Indeed, they not unfrequently injure assailants more than assailed; so it was not in the days of Galileo. These weapons were then in all their sharpness and venom.

The first champion who appears against him is Bellarmin, one of the greatest of theologians, and one of the poorest of scientists. He was earnest, sincere, learned, but made the fearful mistake for the world, of applying to science, direct, literal interpretation of Scripture.[1]

The weapons which men of Bellarmin's stamp used were theological. They held up before the world the dreadful consequences which must result to Christian theology were the doctrine to prevail that the heavenly bodies revolve about the sun, and not about the earth. Their most tremendous theologic engine against Galileo was the idea that his pretended discovery vitiated the whole Christian plan of salvation. Father Le Gazrée declared that it "cast suspicion on the doctrine of the Incarnation." Others declared that it "upset the whole basis of theology; that if the earth is a planet, and one among several planets, it cannot be that any such great things have been done especially for it, as the Christian doctrine teaches. If there are other planets, since God makes nothing in vain, they must be inhabited; but how can these inhabitants be descended from Adam? How can they trace back their origin to Noah's ark? How can they have been redeemed by the Saviour?"[2]

Nor was this argument confined to the theologians of the Roman Church; Melanchthon, Protestant as he was, had already used it in his attacks upon the ideas of Copernicus and his school.[3]

In addition to this prodigious engine of war, there was kept up a terrific fire of smaller artillery in the shape of texts and scriptural extracts. Some samples of these weapons may be interesting.

When Galileo had discovered the four satellites of Jupiter,[4] the

[1] For Bellarmin's view *see* Quinet, "Jesuits," vol. ii., p. 189. For other objectors and objections, *see* Libri, "Histoire des Sciences Mathématiques en Italie," vol. iv., pp. 233, 234; also, "Private Life of Galileo," compiled from his correspondence and that of his eldest daughter, Boston, 1870 (an excellent little book).

[2] *See* Trouessart, cited in Flammarion, "Mondes Imaginaires et Réels," sixième édition, pp. 315, 316.

[3] "Initia Doctrinæ Physicæ," pp. 220, 221.

[4] *See* Delambre as to the discovery of the satellites of Jupiter being the turning-point

whole thing was denounced as impossible and impious. It was argued that the Bible clearly showed by all applicable types, that there could be only seven planets; that this was proved by the seven golden candlesticks of the Apocalypse, by the seven-branched candlestick of the Tabernacle, and by the seven churches of Asia.[1]

In a letter to his friend Renieri, Galileo gives a sketch of the dealings of the Inquisition with him. He says: "The Father Commissary, Lancio, was zealous to have me make amends for the scandal I had caused in sustaining the idea of the movement of the earth. To all my mathematical and other reasons he responded nothing but the words of Scripture, '*Terra autem in æternum stat.*'"[2]

It was declared that the doctrine was proved false by the standing still of the sun for Joshua; by the declarations that "the foundations of the earth are fixed so firm that they cannot be moved," and that the sun "runneth about from one end of heaven to the other."[3]

The Dominican father, Caccini, preached a sermon from the text, "Ye men of Galilee, why stand ye gazing up into heaven?" and this wretched pun was the first of a series of sharper weapons, for before Caccini finishes he insists that "geometry is of the devil," and that "mathematicians should be banished as the authors of all heresies."[4]

For the final assault, the park of heavy artillery was at last wheeled into place. You see it on all the scientific battle-fields. It consists of general denunciation, and Father Melchior Inchofer, of the Jesuits, brought his artillery to bear well on Galileo with this declaration: that the opinion of the earth's motion is, of all heresies, the most abominable, the most pernicious, the most scandalous; that the immobility of the earth is thrice sacred; that argument against the immortality of the soul, the Creator, the incarnation, etc., should be tolerated sooner than an argument to prove that the earth moves.[5]

In vain did Galileo try to prove the existence of satellites by showing them to the doubters through his telescope. They either declared it impious to look, or, if they did see them, denounced them as illusions from the devil. Good Father Clavius declared that "to see satellites of Jupiter, men had to make an instrument which would create them."[6]

with the heliocentric doctrine. As to its effects on Bacon, *see* Jevons, "Principles of Science," vol. ii., p. 298.

[1] For argument drawn from the candlestick and seven churches, *see* Delambre.

[2] For Galileo's letter to Renieri, *see* Cantu, "Hist. Universelle," Paris, 1855, xv., p. 477, note.

[3] Cantu, "Histoire Universelle," vol. xv., p. 478.

[4] For Caccini's attack, *see* Delambre, "Hist. de l'Astron.," disc. prélim., p. xxii., also Libri, "Hist. des Sciences Math.," vol. iv., p. 232.

[5] *See* Inchofer's "Tractatus Syllepticus," cited in Galileo's letter to Deodati, July 28, 1634.

[6] Libri, vol. iv., p. 211. De Morgan, "Paradoxes," p. 26, for account of Father Clavius. It is interesting to know that Clavius, in his last years, acknowledged that "the whole system of the heavens is broken down, and must be mended."

In vain did Galileo try to protect himself by his famous letter to the duchess, in which he insisted that theological reasoning should not be applied to science. The rest of the story the world knows by heart; none of the recent attempts have succeeded in mystifying it. The whole world will remember forever how Galileo was subjected certainly to indignity and imprisonment equivalent to physical torture;[1] how he was at last forced to pronounce publicly, and on his knees, his recantation as follows: "I, Galileo, being in my seventieth year, being a prisoner and on my knees, and before your eminences, having before my eyes the Holy Gospel, which I touch with my hands, abjure, curse, and detest, the error and heresy of the movement of the earth."[2]

He was vanquished indeed, for he had been forced, in the face of all coming ages, to perjure himself. His books were condemned, his friends not allowed to erect a monument over his bones. To all appearance his work was overthrown.

Do not understand me here as casting blame on the Roman Church as such. It must, in fairness, be said that some of its best men tried to stop this great mistake; even the pope himself would have been glad to stop it; but the current was too strong.[3] The whole of the civilized world was at fault, Protestant as well as Catholic, and not any particular part of it. It was not the fault of religion, it was the fault of the short-sighted views which narrow-minded, loud-voiced men are ever prone to mix in with religion, and to insist *is* religion.[4]

Were there time, I would refer at length to some of the modern mystifications of the history of Galileo. One of the latest seems to have for its groundwork the theory that Galileo was condemned for a breach of good taste and etiquette. But those who make this defense make the matter infinitely worse for those who committed the great

[1] It is not probable that torture in the ordinary sense was administered to Galileo. *See* Th. Martin, "Vie de Galilée," for a fair summing up of the case.

[2] For text of the abjuration, *see* "Private Life of Galileo," Appendix. As to the time when the decree of condemnation was repealed, various authorities differ. Artaud, p. 307, cited in an apologetic article in *Dublin Review*, September, 1865, says that Galileo's famous dialogue was published in 1744, at Padua, entire, and with the usual approbations. The same article also declares that in 1818 the ecclesiastical decrees were repealed by Pius VII., in full Consistory. Whewell says that Galileo's writings, after some opposition, were expunged from the "Index Expurgatorius," in 1818. Cantu, an authority rather favorable to the Church, says that Copernicus's work remained on the "Index" as late as 1835. Cantu, "Histoire Universelle," vol., xv., p. 483.

[3] For Baronius's remark *see* De Morgan, p. 26. Also Whewell, vol. i., p. 394.

[4] For an exceedingly striking statement, by a Roman Catholic historian of genius, as to popular demand for persecution, and the pressure of the lower strata, in ecclesiastical organizations, for cruel measures, *see* Balmès, "Le Protestantisme comparé au Catholicisme," etc., 4th ed., Paris, 1855, vol. ii. Archbishop Spaulding has something of the same sort in his Miscellanies. L'Epinois, "Galilée," p. 22, *et seq.*, stretches this as far as possible, to save the reputation of the Church in the Galileo matter.

wrong. They deprive it of its only palliation, mistaken conscientiousness.[1]

Nor was this the worst loss to the earth.

There was then in Europe one of the greatest thinkers ever given to mankind. Mistaken though many of his theories were, they were fruitful in truths. The man was Réné Descartes. The scientific warriors had stirred new life in him, and he was working over and summing up in his mighty mind all the researches of his time. The result must make an epoch in the history of man. His aim was to combine all knowledge and thought into a "Treatise on the World." His earnestness he proved by the eleven years which he gave to the study of anatomy alone. Petty persecution he had met often, but the fate of Galileo robbed him of all hope, of all energy. The battle seemed lost. He gave up his great plan forever.[2]

But champions pressed on. Campanella, full of vagaries as he was, wrote his "Apologia pro Galileo," though for that and other heresies, religious and political, he seven times underwent torture.[3]

And Kepler comes. He leads science on to greater victories. He throws out the minor errors of Kopernik. He thinks and speaks as

[1] *See Dublin Review*, as above. Whewell, vol. i., 393. Citation from Marini: "Galileo was punished for trifling with the authorities to which he refused to submit, and was punished for obstinate contumacy, not heresy." The sufficient answer to all this is that the words of the inflexible sentence designating the condemned books are: "*Libri omnes qui affirmant telluris motum.*" *See* Bertrand, p. 59. It has also been urged that "Galileo was punished not for his opinion, but for basing it on Scripture." The answer to this may be found in the Roman Index of 1704, in which are noted for condemnation "*Libri omnes docentes mobilitatem terræ et inmobilitatem solis.*" For the way in which, when it was found convenient in argument, Church apologists insisted that it *was* "the Supreme Chief of the Church, by a pontifical decree, and not certain cardinals," who condemned Galileo and his doctrine, *see* Father Gazrée's letter to Gassendi in Flammarion, "Pluralité des Mondes," p. 427. For the way in which, when necessary, Church apologists asserted the very contrary of this, declaring that "it was issued in a doctrinal decree of the Congregation of the Index, and *not* as the Holy Father's teaching," *see Dublin Review*, September, 1865. And for the most astounding attempt of all, to take the blame off the shoulders of both pope and cardinals, and place it upon the Almighty, see the following words of the article above cited: "But it may well be doubted whether the Church did retard the progress of scientific truth. What retarded it was the circumstance that God has thought fit to express many texts of Scripture in words which have every appearance of denying the earth's motion. But it is God who did this, not the Church; and, moreover, since he thought fit so to act as to retard the progress of scientific truth, it would be little to her discredit even if it were true that she had followed his example."—*Dublin Review*, September, 1865, p. 419. For the best summary of the various attempts, and for replies to them in a spirit of judicial fairness, *see* Th. Martin, "Vie de Galilée." This is probably the best book ever written on the Galileo question. The bibliography at the close is very valuable.

[2] Humboldt, "Cosmos," London, 1851, vol. iii., p. 21. Also Lange, "Geschichte des Materialismus," vol. i., p. 222, where the letters of Descartes are given, showing his despair, and the giving up of his best thoughts and works to preserve peace with the Church. Also Jolly, "Hist. du Mouvement Intellectuel au XVI^e^ Siècle," vol. i., p. 390.

[3] Libri, pp. 149, *et seq.*

one inspired. His battle is severe. He is sometimes abused, sometimes ridiculed, sometimes imprisoned. Protestants in Styria and at Tübingen, Catholics at Rome press upon him,[1] but Newton, Huyghens and the other great leaders follow, and to science remains the victory.

And yet the war did not wholly end. During the seventeenth century, in all France, no one dared openly teach the Copernican theory, and Cassini, the great astronomer, never declared it.[2] In 1672, Father Riccioli, a Jesuit, declared that there were precisely forty-nine arguments for the Copernican theory and seventy-seven against it; so that there remained twenty-eight reasons for preferring the orthodox theory.[3] Toward the end of the seventeenth century also, even Bossuet, the "eagle of Meaux," among the loftiest of religious thinkers, declared for the Ptolemaic theory as the Scriptural theory,[4] and in 1746 Boscovich, the great mathematician of the Jesuits, used these words: "As for me, full of respect for the Holy Scriptures and the decree of the Holy Inquisition, I regard the earth as immovable; nevertheless, for simplicity in explanation, I will argue as if the earth moves, for it is proved that of the two hypotheses the appearances favor that idea."[5]

The Protestantism of England was no better. In 1772 sailed the famous English expedition for scientific discovery under Cook. The greatest by far of all the scientific authorities chosen to accompany it was Dr. Priestley. Sir Joseph Banks had especially invited him; but the clergy of Oxford and Cambridge intervened. Priestley was considered unsound in his views of the Trinity; it was declared that this would vitiate his astronomical observations; he was rejected and the expedition crippled.[6]

Nor has the opposition failed even in our own time. On the 5th of May, 1826, a great multitude assembled at Thorn to celebrate the three hundredth anniversary of Kopernik, and to unveil Thorwaldsen's statue of him.

Kopernik had lived a pious, Christian life. He was well known

[1] Fromundus, speaking of Kepler's explanation, says: "Vix teneo ebullientem risum." It is almost equal to the *New York Church Journal*, speaking of John Stuart Mill as "that small sciolist," and of the preface to Dr. Draper's recent work as "chippering." How a journal generally so fair in its treatment of such subjects can condescend to use such weapons is one of the wonders of modern journalism. For Protestant persecution of Kepler, *see* vol. i., p. 392.

[2] For Cassini's position, *see* Henri Martin, "Hist. de France," vol. xiii., p. 175.

[3] Daunou, "Études Historiques," vol. ii., p. 439.

[4] Bossuet, *see* Bertrand, p. 41.

[5] Boscovich. This was in 1746, but in 1785 Boscovich seemed to feel his position in view of history, and apologized abjectly. Bertrand, pp. 60, 61. *See* also Whewell's notice of Le Sueur and Jacquier's introduction to their edition of Newton's "Principia." For the most recent proofs of the Copernican theory, by discoveries of Bunsen, Bischoff, Benzenburg, and others, *see* Jevons, "Principles of Science."

[6] *See* Weld, "History of the Royal Society," vol. ii., p. 56, for the facts and the admirable letter of Priestley upon this rejection.

for unostentatious Christian charity. With his religious belief no fault had ever been found. He was a canon of the church of Frauenberg, and over his grave had been written the most touching of Christian epitaphs.

Naturally, then, the people expected a religious service. All was understood to be arranged for it. The procession marched to the church and waited. The hour passed, no priest appeared; none could be induced to appear. Kopernik, simple, charitable, pious, one of the noblest gifts of God to the service of religion as well as science, was still held to be a reprobate. Seven years after that, his book was still standing on the "Index of Books prohibited to Christians."[1]

Nor has this warfare against dead champions of science been carried on only by the older Church.

On the 10th of May, 1859, was buried Alexander von Humboldt. His labors were among the greatest glories of the century, and his funeral one of the most imposing that Berlin had ever seen: among those who honored themselves by their presence was the prince regent—the present emperor. But of the clergy it was observed that none were present save the officiating clergyman and a few regarded as unorthodox.[2]

Nor have attempts to renew the battle been wanting in these latter days. The attempt in the Church of England, in 1864, to fetter Science—which was brought to ridicule by Herschel, Bowring, and De Morgan; the Lutheran assemblage at Berlin, in 1868, to protest against "science falsely so called," in the midst of which stood Pastor Knak denouncing the Copernican theory; the "Syllabus," the greatest mistake of the Roman Church, are all examples of this.[3]

And now, what has been won by either party in this long and terrible war? The party which would subordinate the methods and aims of science to those of theology, though in general obedient to deep convictions, had given to Christianity a series of the worst blows it had ever received. They had made large numbers of the best men in Europe hate it. Why did Ricetto and Bruno and Vanini, when the crucifix was presented to them in their hours of martyrdom, turn from that blessed image with loathing?[4] Simply because Christianity had been made to them identical with the most horrible oppression of the mind.

Worse than that, the well-meaning defenders of the faith had

[1] Bertrand, "Fondateurs de l'Astron. Mod.," p. 61. Flammarion, "Vie de Copernic," chap. ix.

[2] Bruhns and Lassell, "Life of Humboldt," London, 1873, vol. ii., p. 411.

[3] For the very amusing details of the English attempt, and of the way in which it was met, *see* De Morgan, "Paradoxes," p. 42. For Pastor Knak and his associates, *see Revue des Deux Mondes*, 1868.

[4] For a striking account, gathered from eye-witnesses, of this frightful scene at the execution of Bruno, *see* letter of Scioppius in appendix to vol. iv. of Libri, "Hist. des Mathématiques."

wrought into the very fibre of the European heart that most unfortunate of all ideas, the idea that there is a necessary antagonism between science and religion. Like the landsman who lashes himself to the anchor of the sinking ship, they had attached the great fundamental doctrines of Christianity, by the strongest cords of logic which they could spin, to these mistaken ideas in science, and the advance of knowledge had wellnigh engulfed them.

On the other hand, what had science done for religion? Simply this: Kopernik, escaping persecution only by death; Giordano Bruno, burned alive as a monster of impiety; Galileo, imprisoned and humiliated as the worst of misbelievers; Kepler, hunted alike by Protestant and Catholic, had given to religion great new foundations, great new, ennobling conceptions, a great new revelation of the might of God.

Under the old system we have that princely astronomer, Alfonso of Castile, seeing the poverty of the Ptolemaic system, yet knowing no other, startling Europe with the blasphemy that if he had been present at creation he could have suggested a better ordering of the heavenly bodies. Under the new system you have Kepler, filled with a religious spirit, exclaiming, "I do think the thoughts of God."[1] The difference in religious spirit between these two men marks the conquest made in this, even by science, for religion. But we cannot leave the subject of astronomy without noticing the most recent warfare. Especially interesting is it because at one period the battle seemed utterly lost, and then was won beautifully, thoroughly, by a legitimate advance in scientific knowledge. I speak of the Nebular Hypothesis.

The sacred writings of the Jews which we have inherited speak clearly of the creation of the heavenly bodies by direct intervention, and for the convenience of the earth. This was the view of the Fathers of the Church, and was transmitted through the great doctors in theology.

More than that, it was crystallized in art. So have I seen, over the portal of the Cathedral of Freiburg, a representation of the Almighty making and placing numbers of wafer-like suns, moons, and stars; and at the centre of all, platter-like and largest of all, the earth.[2] The lines on the Creator's face show that he is obliged to contrive; the lines of his muscles show that he is obliged to toil. Naturally, then, did sculptors and painters of the mediæval and early modern period represent the Almighty as weary after labor, and enjoying dignified repose.

These ideas, more or less gross in their accompaniments, passed into the popular creed of the modern period.

[1] As a pendant to this ejaculation of Kepler may be cited those wondrous words of Linnæus: "Deum omnipotentem a tergo transeuntem vidi et obstupui."

[2] For papal bulls representing the earth as a flat disk, see Daunou, "Études Historiques," vol. ii., p. 421.

But about the close of the last century, Bruno having guessed the fundamental fact of the nebular hypothesis, and Kant having reasoned out its foundation idea, Laplace developed it, showing the reason for supposing that our own solar system, in its sun, planets, satellites, with their various motions, distances, and magnitudes, is a natural result of the diminishing heat of a nebulous mass—a result obeying natural laws.

There was an outcry at once against the "atheism" of the scheme. The war raged fiercely. Laplace claimed that there were in the heavens many nebulous patches yet in the gaseous form, and pointed them out. He showed by laws of physics and mathematical demonstration that his hypothesis accounted in a most striking manner for the great body of facts, and, despite clamor, was gaining ground, when the improved telescopes resolved some of the patches of nebulous matter into multitudes of stars.

The opponents of the nebular hypothesis were overjoyed. They sang pæans to astronomy, because, as they said, it had proved the truth of Scripture.

They had jumped to the conclusion that all nebulæ must be alike—that if some are made up of systems of stars all must be so made up; that none can be masses of attenuated gaseous matter, because some are not.

Science, for a time, halted. The accepted doctrine became this—that the only reason why all the nebulæ are not resolved into distinct stars is, because our telescopes are not sufficiently powerful.

But in time came that wonderful discovery of the spectroscope and spectrum analysis, and this was supplemented by Fraunhofer's discovery that the spectrum of an ignited gaseous body is discontinuous, with interrupting lines; and this, in 1846, by Draper's discovery that the spectrum of an ignited solid is continuous, with no interrupting lines. And now the spectroscope was turned upon the nebulæ and about one-third of them were found to be gaseous.

Again the nebular hypothesis comes forth stronger than ever. The beautiful experiment of Plateau on the rotation of a fluid globe comes in to strengthen if not to confirm it. But what was likely to be lost in this? Simply a poor conception of the universe. What to be gained? A far more worthy idea of that vast power which works in the universe, in all things by law, and in none by caprice.[1]

[1] For Bruno's conjecture (in 1591), *see* Jevons, vol. ii., p. 299. For Kant's part in the nebular hypothesis, *see* Lange, "Geschichte des Materialismus," vol. i., p. 266. For value of Plateau's beautiful experiment very cautiously estimated, *see* W. Stanley Jevons, "Principles of Science," London, 1874, vol. ii., p. 36. Also Elisée Réclus, "The Earth," translated by Woodward, vol. i., pp. 14–18, for an estimate still more careful. For a general account of discoveries of nature of nebulæ by spectroscope, *see* Draper, "Conflict between Religion and Science." For a careful discussion regarding the spectra of solid, liquid, and gaseous bodies, *see* Schellen, "Spectrum Analysis," pp. 100, *et seq.* For a very thorough discussion of the bearings of discoveries made by spectrum analysis upon the

The great series of battles to which I next turn with you were fought on those fields occupied by such sciences as chemistry and natural philosophy.

Even before those sciences were out of their childhood, while yet they were tottering mainly toward childish objects and by childish steps, the champions of that same old mistaken conception of rigid scriptural interpretation began the war. The catalogue of chemists and physicists persecuted or thwarted would fill volumes; from them I will select just three as representative men.

First of these I take Albert of Bollstadt, better known in the middle ages as Albert the Great. In the thirteenth century he stands forth as the greatest scholar in Germany. Fettered though he was by the absurd methods of his time, led astray as he was by the scholastic spirit, he has conceived ideas of better methods and aims. His eye pierces the mists of scholasticism, he sees the light and draws the world toward it. He stands among the great pioneers of modern physical and natural science. He gives foundations to botany and chemistry, and Humboldt finds in his works the germ of the comprehensive science of physical geography.[1]

The conscience of the time, acting as it supposed in defense of religion, brought out a missile which it hurled with deadly effect. You see those mediæval scientific battle-fields strewn with such: it was the charge of sorcery, of unlawful compact with the devil.

This missile was effective. You find it used against every great investigator of Nature in those times and for centuries after. The list of great men charged with magic, as given by Naudé, is astounding. It includes every man of real mark, and the most thoughtful of the popes, Sylvester II. (Gerbert), stands in the midst of them. It seemed to be the received idea that, as soon as a man conceived a love to study the works of God, his first step must be a league with the devil.[2]

This missile was hurled against Albert. He was condemned by the great founder of the Dominican order himself. But more terrible weapons than this missile were added to it, to make it effective. Many an obscure chemist paid a terrible penalty for wishing to be wiser than his time; but I pass to the greater martyrs.

I name, next, Roger Bacon. His life and work seem until recent-

nebular hypothesis, ibid., pp. 532–537. For a presentation of the difficulties yet unsolved, *see* article by Plummer, in London *Popular Science Review* for January, 1875. For excellent short summary of recent observations and thought on this subject, *see* T. Sterry Hunt, "Address at the Priestley Centennial," pp. 7, 8. For an interesting modification of this hypothesis, *see* Proctor's recent writings.

[1] "Il était aussi très-habile dans les arts mécaniques, ce que le fit soupçonner d'être sorcier."—Sprengel, "Histoire de la Médecine," vol. ii., p. 389.

[2] For the charge of magic against scholars and others, *see* Naudé, "Apologie pour les grands hommes accusés de Magie," *passim*. Also, Maury, "Hist. de la Magie," troisième édit., pp. 214, 215. Also Cuvier, "Hist. des Sciences Naturelles," vol. i., p. 396.

ly to have been generally misunderstood. He has been ranked as a superstitious alchemist who stumbled upon some inventions; but more recent investigation has revealed him to be one of the great masters in human progress.

The advance of sound historical judgment seems likely to reverse the positions of the two who bear the name of Bacon. Bacon of the chancellorship and the "Novum Organon" seems to wane. Bacon of the prison-cell and the "Opus Majus" seems to grow brighter.[1]

Roger Bacon's work, as it is now revealed to us, was wonderful. He wrought with power in philosophy and in all sciences, and his knowledge was sound and exact. By him, more than by any other man of the middle ages, was the world put on the most fruitful paths of science—the paths which have led to the most precious inventions. Clocks, lenses, burning specula, telescopes, were given by him to the world, directly or indirectly. In his writings are found formulæ for extracting phosphorus, manganese, and bismuth. It is even claimed that he investigated the power of steam. He seems to have very nearly reached also some of the principal doctrines of modern chemistry. His theory of investigation was even greater than these vast results. In an age when metaphysical subtilizing was alone thought to give the title of scholar, he insisted on *real* reasoning and the aid of natural science by mathematics. In an age when experimenting was sure to cost a man his reputation and was likely to cost him his life, he insisted on experiment and braved all its risks. Few greater men have lived. As we read the sketch given by Whewell of Bacon's process of reasoning regarding the refraction of light, he seems fairly inspired.

On this man came the brunt of the battle. The most conscientious men of his time thought it their duty to fight him, and they did it too well. It was not that he disbelieved in Christianity, *that* was never charged against him. His orthodoxy was perfect. He was attacked and condemned, in the words of his opponents, "*propter quasdam novitates suspectas.*"

He was attacked, first of all, with that goodly old missile, which, with the epithets "infidel" and "atheist," has decided the fate of so many battles—the charge of magic and compact with Satan.

He defended himself with a most unfortunate weapon—a weapon which exploded in his hands and injured him more than the enemy, for he argued against the idea of compacts with Satan, and showed that much which is ascribed to demons results from natural means. This added fuel to the flame. To limit the power of Satan was deemed hardly less impious than to limit the power of God.

The most powerful protectors availed him little. His friend Guy

[1] For a very contemptuous statement of Lord Bacon's claim to his position as a philosopher, *see* Lange, "Geschichte des Materialismus," Leipsic, 1874, vol. i., p. 219. *See* also Jevons, "Principles of Science," London, 1874, vol. ii., p. 298.

Foulkes having been made pope, Bacon was for a time shielded, but the fury of the enemy was too strong. In an unpublished letter, Blackstone declares that when, on one occasion, Bacon was about to perform a few experiments for some friends, all Oxford was in an uproar. It was believed that Satan was let loose. Everywhere were priests, fellows, and students rushing about, their garments streaming in the wind, and everywhere resounded the cry, "Down with the conjurer!" and this cry "Down with the conjurer" resounded from cell to cell and hall to hall.[1]

But the attack took a shape far more terrible. The two great religious orders, Franciscan and Dominican, vied with each other in fighting the new thought in chemistry and philosophy. St. Dominic, sincere as he was, solemnly condemned research by experiment and observation. The general of the Franciscan order took similar grounds.

In 1243 the Dominicans solemnly interdicted every member of their order from the study of medicine and natural philosophy; and, in 1287, this interdiction was extended to the study of chemistry.[2]

Another weapon began to be used upon the battle-fields of that time with much effect. The Arabs had made noble discoveries in science. Averroes had, among many, divided the honors with St. Thomas Aquinas. These facts gave the new missile. It was the epithet "Mahometan." This, too, was flung with effect at Bacon.[3]

Bacon was at last conquered. He was imprisoned for fourteen years. At the age of eighty years he was released from prison, but death alone took him beyond the reach of his enemies. How deeply the struggle had racked his mind may be gathered from that last afflicting declaration of his: "Would that I had not given myself so much trouble for the love of science!"

Sad is it to think of what this great man might have given to the world had the world not refused the gift. He held the key of treasures which would have freed mankind from ages of error and misery. With his discoveries as a basis, with his method as a guide, what might not the world have gained! Nor was the wrong done to that age alone. It was done to this age also. The nineteenth century was robbed at the same time with the thirteenth. But for that inter-

[1] Whewell, vol. i., pp. 367, 368. Draper, p. 438. Saisset, "Descartes et ses Précurseurs," deuxième édition, pp. 397, *et seq.* Nourrisson, "Progrès de la pensée humaine," pp. 271, 272. Sprengel, "Histoire de la Médecine," Paris, 1865, vol. ii., p. 397. Cuvier, "Histoire des Sciences Naturelles," vol. i., p. 417. As to Bacon's orthodoxy, *see* Saisset, pp. 53, 55. For special examination of causes of Bacon's condemnation, *see* Waddington, cited by Saisset, p. 14. On Bacon as a sorcerer, *see* Featherstonaugh's article in *North American Review*. For a good example of the danger of denying full power of Satan, even in much more recent times, and in a Protestant country, *see* account of treatment of Bekker's "Monde Enchanté" by the theologians of Holland, in Nisard, "Histoire des Livres Populaires," vol. i., pp. 172, 173.

[2] Henri Martin, "Hist. de France," vol. iv., p. 283.

[3] On Bacon as a "Mahometan," *see* Saisset, p. 17

ference with science, this nineteenth century would, without doubt, be enjoying discoveries which will not be reached before the twentieth century. Thousands of precious lives shall be lost in this century, tens of thousands shall suffer discomfort, privation, sickness, poverty, ignorance, for lack of discoveries and methods which, but for this mistaken religious fight against Bacon and his compeers, would now be blessing the earth.

In 1868 and 1869, sixty thousand children died in England and in Wales of scarlet fever; probably nearly as many died in this country. Had not Bacon been hindered we should have had in our hands, by this time, the means to save two-thirds of these victims, and the same is true of typhoid, typhus, and that great class of diseases of whose physical causes Science is just beginning to get an inkling. Put together all the efforts of all the atheists who have ever lived, and they have not done so much harm to Christianity and the world as has been done by the narrow-minded, conscientious men who persecuted Roger Bacon.[1]

Roger Bacon was vanquished. For ages the champions of science were crippled; but the "good fight" was carried on. The Church itself furnishes heroes of science. Antonio de Dominis relinquishes his archbishopric of Spalatro, investigates the phenomena of light, and dies in the clutches of the Inquisition.[2]

Pierre de la Ramée stands up against Aristotelianism at Paris. A royal edict, sought by the Church, stopped his teaching, and the massacre of St. Bartholomew ended his life.

Somewhat later, John Baptist Porta began his investigations. Despite many absurdities, his work was most fruitful. His book on meteorology was the first in which sound ideas were broached. His researches in optics gave the world the camera obscura, and, possibly, the telescope. He encountered the same old policy of conscientious men. The society founded by him for physical research, "I Secreti," was broken up, and he was summoned to Rome and censured.[3]

In 1624, some young chemists of Paris having taught the experimental method, and cut loose from Aristotle, the Faculty of Theology besets the Parliament of Paris, and the Parliament prohibits this new chemical teaching under penalty of death.[4]

The war went on in Italy. In 1657 occurred the first sitting of

[1] For proofs that the world is steadily working toward great discoveries as to the cause and prevention of zymotic diseases and of their propagation, *see* Beale's "Disease Germs," Baldwin Latham's "Sanitary Engineering," Michel Lévy, "Traité d'Hygiène Publique et Privée," Paris, 1869. And for very thorough summaries, *see* President Barnard's paper read before Sanitary Congress in New York, 1874, and Dr. J. C. Dalton's "Anniversary Discourse, on the Origin and Propagation of Disease," New York, 1874.

[2] Antonio de Dominis, *see* Montucla, "Hist. des Mathématiques," vol. i., p. 705. Humboldt, "Cosmos." Libri, vol. iv., pp. 145, *et seq.*

[3] Sprengel, "Hist. de la Médecine, iii., p. 239. Also Musset-Parthay.

[4] Henri Martin, "Histoire de France," vol. xii., pp. 14, 15.

the *Accademia del Cimento*, at Florence, under the presidency of Prince Leopold dei Medici. This Academy promised great things for science. It was open to all talent. Its only fundamental law was "the repudiation of any favorite system or sect of philosophy, and the obligation to investigate Nature by the pure light of experiment."

The new Academy entered into scientific investigations with energy. Borelli in mathematics, Redi in natural history, and many others, pushed on the boundaries of knowledge. Heat, light, magnetism, electricity, projectiles, digestion, the incompressibility of water, were studied by the right method and with results that enriched the world.

The Academy was a fortress of science, and siege was soon laid to it. The votaries of scholastic learning denounced it as irreligious. Quarrels were fomented. Leopold was bribed with a cardinal's hat and drawn away to Rome; and, after ten years of beleaguering, the fortress fell: Borelli was left a beggar; Oliva killed himself in despair.[1]

From the dismissal of the scientific professors from the University of Salamanca by Ferdinand VII. of Spain, in the beginning of this century, down to sundry dealings with scientific men in our own land and time, we see the same war continued.

Joseph de Maistre, uttering his hatred of physical sciences, declaring that man has paid too dearly for them, asserting that they must be subjected to theology, likening them to fire—good when confined but fearful when scattered about—this brilliant thinker has been the centre of a great opposing camp in our own time—an army of good men who cannot relinquish the idea that the Bible is a text-book of science.

[*To be continued.*]

NATURAL HISTORY OF THE KANGAROO.

By ST. GEORGE MIVART, F.R.S.

THE kangaroos have now become familiar objects to all who visit our Zoölogical Gardens, or who are familiar with any considerable zoölogical museum.

Their general external form, when seen in the attitude they habitually assume when grazing (with their front limbs touching the ground),

[1] Napier, "Florentine History," vol. v., p. 485. Tiraboschi, "Storia della Literatura." Henri Martin, "Histoire de France." Jevons, "Principles of Science," vol. ii., pp. 36–40. Libri, in his "Essai sur Galilée," p. 37, says that Oliva was summoned to Rome and so tortured by the Inquisition that, to escape further cruelty, he ended his life by throwing himself from a window. For closing, by church authority, of the Academy, "I Secreti," instituted for scientific investigation at an earlier period, *see* reference to Porta in this article. On Porta, *see* Sprengel, "Histoire de la Médecine," vol. iii., p. 239.

may have recalled to mind, more or less, the appearance presented by some hornless deer. Their chief mode of locomotion (that jumping action necessitated by the great length of the hind-limbs) must be familiar to all who have observed them living, and also, very probably, the singular mode in which the young are carried in a pouch of skin in the front of the belly of the mother.

But "What is a kangaroo?" The question will raise in the minds of those who are not naturalists the image of some familiar circum-

FIG. 1.—KANGAROO (*Macropus*).

stances like those just referred to. But such image will afford no real answer to the question. To arrive at *such* an answer it is necessary to estimate correctly in what relation the kangaroo stands to other

animals—its place in the scale of animated beings—as also its relations to space and time; that is, its distribution over the earth's surface to-day, in connection with that of other animals more or less like it, and its relation to the past life of this planet, in connection with similar relations of animals also more or less like it. In other words, to understand what a kangaroo is, we must understand its zoölogical, geographical, and geological conditions. And my task in this paper is to make these conditions as clear as I can, and so to enable the reader to really answer the question, "What is a kangaroo?"

But before proceeding to these matters, let us look at our kangaroo a little closer, and learn something of its structure, habits, and history, so as to have some clear conceptions of the kangaroo considered by itself, before considering its relations with the universe (animate and inanimate) about it.

The kangaroo (Fig. 1) is a quadruped, with very long hind-limbs and a long and rather thick tail. Its head possesses rather a long muzzle, somewhat like that of a deer, with a pair of rather long ears. Each fore-paw has five toes, urnished with claws. Each hind-limb has but two large and conspicuous toes, the inner one of which is much the larger, and bears a very long and strong claw (Fig. 2). On the inner

FIG. 2.—FOOT OF KANGAROO.

side of this is what appears to be a very minute toe, furnished with two small claws. An examination of the bones of the foot shows us, however, that it really consists of two very slender toes united together in a common fold of skin. These toes answer to the second and third toes of our own foot, and there is no representative of our great-toe—not even that part of it which is inclosed in the substance of our foot, called the *inner metatarsal bone*. Two other points are specially noteworthy in the skeleton. The first of these is that the pelvis (or bony girdle to which the hind-limbs are articulated, and by which they are connected with the back-bone) has two elongated bones extending upward from its superior margin in front (Fig. 4, *a*). These are called marsupial bones, and lie within the flesh of the front of the animal's belly. The other point is that the lower, hinder portion of each side of the lower jaw (which portion is technically called the "*angle*") is bent inward, or "inflected," and not continued directly backward in the same plane as the rest of the lower jaw.

A certain muscle, called the cremaster muscle, is attached to each

marsupial bone, and thence stretches itself over the inner or deep surface of the adjacent mammary gland or "breast," which is situated low down, and not in the breast at all.

The kangaroo's teeth consist of three on each side in the front of the mouth, and one on each side below. These eight teeth are what are called incisors. At the back of the mouth there are five grinding-teeth on each side above and five below, and between the upper grinders and incisors another pointed tooth, called a canine, may or may not be interposed. Such a set of teeth is indicated by the following formula, where I stands for incisors, C for canines, and M for grinding-teeth or "molars." The number above each line indicates the teeth of each denomination which exist on one side of the upper jaw, and the lower number those of the lower jaw:

$$I\ \frac{3}{1}\ C\ \frac{0}{0}\ \text{or}\ \frac{1}{0}\ M\ \frac{5}{5} = \frac{9}{6}\ \text{or}\ \frac{8}{6}$$

The total number of incisor teeth of *both* sides of each jaw may therefore be expressed thus: $I\ \frac{6}{2}$.

Such is the general structure of an adult kangaroo. At birth it is strangely different from what it ultimately becomes.

It is customary to speak of the human infant as exceptionally helpless at birth and after it, but it is at once capable of vigorous sucking, and very early learns to seek the nipple. The great kangaroo, standing some six feet high, is at birth scarcely more than an inch long, with delicate naked skin, and looking like part of an earthworm. But, in such feeble and imperfectly developed condition, the young kangaroo cannot actively suck. The mother therefore places it upon one of her long and slender nipples (the end of which is somewhat swollen), this nipple entering its mouth, and the little creature remaining attached to it. The mother then, by means of the cremaster muscle (before spoken of), squeezes her own milk gland, and so injects milk into the young, which would thus be infallibly choked but for a noticeable peculiarity of its structure, admirably adapted to the circumstances of the case.

In almost all beasts, and in man also, the air-passage or windpipe (which admits air to and from the lungs) opens into the floor of the mouth, behind the tongue and *in front* of the opening of the gullet. Each particle of food, then, as it passes to the gullet, passes over the entrance to the windpipe, but is prevented from falling into it (and so causing death by choking) by the action of a small cartilaginous shield (the *epiglottis*). This shield, which ordinarily stands up in front of the opening into the windpipe, bends back and comes over that opening just when food is passing, and so, at the right moment, almost always prevents food from "going the wrong way." But, in the young kangaroo, the milk being introduced, not by any voluntary act of the

young kangaroo itself, but by the injecting action of its mother, it is evident that, did such a state of things obtain in it as has been just described, the result would be speedily fatal. Did no special provision exist, the young one must infallibly be choked by the intrusion of milk into the windpipe. But there is a special provision for the young kangaroo; the upper part of the windpipe (or larynx), instead of lying as in us, and as in most beasts, widely separated from the hinder opening of the nostrils, is much raised (Fig. 3, *a*). It is in fact so elongated in the young kangaroo that it rises right up into the hinder end of the nasal passage, which embraces it. In this way there is free entrance for air from the nostrils into the windpipe by a

FIG. 3.—1. DISSECTED HEAD OF YOUNG KANGAROO.—*a*, Elongated Larynx; *b*, Cavity of Mouth. 2. Nipple of Mother.

passage shut off from the cavity of the mouth. All the time the milk can freely pass to the back of the mouth and gullet along each side of this elongated larynx, and thus breathing and milk-injection can go on simultaneously, without risk or inconvenience.

The kangaroo browses on the herbage and bushes of more or less open country, and, when feeding, commonly applies its front-limbs to the ground. It readily, however, raises itself on its hind-limbs and strong tail (as on a tripod) when any sound, sight, or smell, alarms its natural timidity (Fig. 1).

Mr. Gould tells us that the natives (where it is found) sometimes hunt these animals by forming a great circle around them, gradually converging upon them, and so frightening them by yells that they become an easy prey to their clubs.

As to its civilized hunters, the same author tells us that kangaroos are hunted by dogs which run entirely by sight, and partake of the nature of the greyhound and deerhound, and, from their great strength and fleetness, are so well adapted for the duties to which they are trained, that the escape of the kangaroo, when it occurs, is owing to peculiar and favorable circumstances; as, for example, the oppressive heat of the day, or the nature of the ground; the former incapacitating the dogs for a severe chase, and the hard ridges, which the kangaroo invariably endeavors to gain, giving him great advantage over his pursuers. On such ground the females in particular will frequently outstrip the fleetest greyhound; while, on the contrary, heavy old

males, on soft ground, are easily taken. Many of these fine kangaroo-dogs are kept at the stock-stations of the interior, for the sole purpose of running the kangaroo and the emu, the latter being killed solely for the supply of oil which it yields, and the former for mere sport or for food for the dogs. Although I have killed the largest males with a single dog, it is not generally advisable to attempt this, as they possess great power, and frequently rip up the dogs, and sometimes even cut

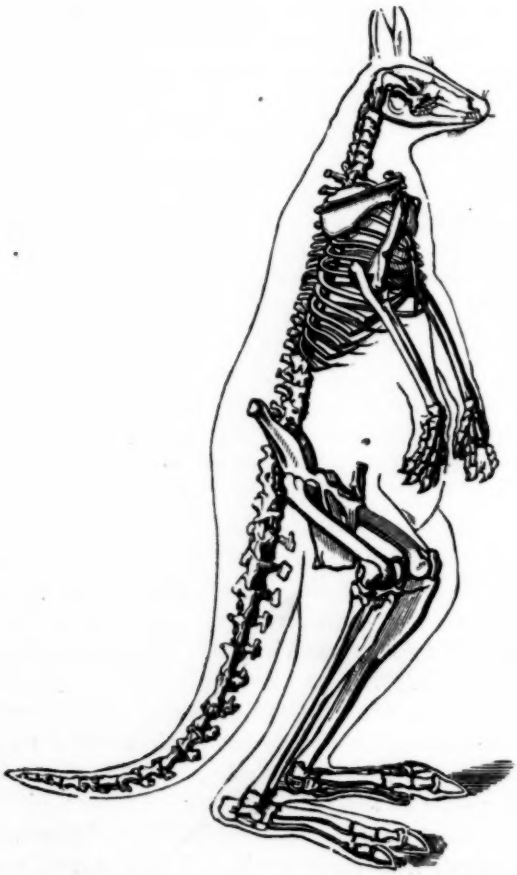


FIG. 4.—SKELETON OF THE KANGAROO.—*a*, Marsupial Bones.

them to the heart with a single stroke of the hind-leg. Three or four dogs are more generally laid on; one of superior fleetness to "pull" the kangaroo, while the others rush in upon it and kill it. It sometimes adopts a singular mode of defending itself, by clasping its short, powerful fore-limbs around its antagonist, then hopping away with it to the nearest water-hole, and there keeping it beneath the water until drowned.

The kangaroo is said to be able to clear even more than fifteen feet at one bound.

Rapidity of locomotion is especially necessary for a large animal inhabiting a country subject to such severe and widely-extending droughts as in Australia. The herbivorous animals which people the plains of Southern Africa—the antelopes—are also capable of very rapid locomotion. In the antelopes, however, as in all hoofed beasts, all the four limbs (front as well as hind) are exclusively used for locomotion. But in kangaroos we have animals requiring to use their front pair of limbs for the purposes of more or less delicate manipulation with respect to the economy of the "pouch." Accordingly, for such creatures to be able to inhabit such a country, the hind pair of limbs must by themselves be fitted alone to answer the purpose of both the front and hind limbs of deer and antelopes. It would seem, then, that the peculiar structure of the kangaroo's limbs is of the greatest utility to it; the front pair serving as prehensile manipulating organs, while the hind pair are, by themselves alone, able to carry the animal great distances with rapidity, and so to traverse wide arid plains in pursuit of rare and distant water. The harmony between structure, habit, and climate, was long ago pointed out by Prof. Owen.

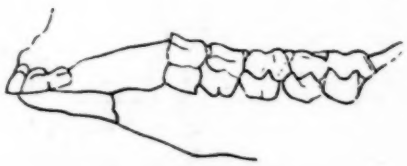


FIG. 5.—TEETH OF KANGAROO.

The kangaroo breeds freely in this country, producing one at a birth. We have young ones every year in our Zoölogical Gardens. A large number of them are reared to maturity, and altogether our kangaroos thrive and do well. One born in our gardens was lately in the habit of still entering the pouch of its mother, although itself bearing a very young one within its own pouch. These animals have been already more or less acclimatized in England. I have myself seen them in grounds at Glastonbury Abbey. Some were so kept in the open by Lord Hill, and some by the Duke of Marlborough. A very fine herd is now at liberty in a park near Tours, in France.

It is a little more than one hundred and five years since the kangaroo was first distinctly seen by English observers. At the recommendation and request of the Royal Society, Captain (then Lieutenant) Cook set sail in May, 1768, in the ship Endeavor, on a voyage of exploration, and for the observation of the transit of Venus of the year 1769, which transit the travelers observed, from the Society Islands, on June 3d of that year. In the spring of the following year the ship

started from New Zealand to the eastern coast of New Holland, visiting, among other places, a spot which, on account of the number of plants found there by Mr. (afterward Sir Joseph) Banks, received the name of Botany Bay. Afterward, when detained in Endeavor River (about 15° south latitude) by the need of repairing a hole made in the vessel by a rock (part of which, fortunately, itself stuck in the hole it made), Captain Cook tells us that on Friday, June 22, 1770, "some of the people were sent on the other side of the water, to shoot pigeons for the sick, who at their return reported that they had seen an animal, as large as a greyhound, of a slender make, a mouse-color, and extremely swift." On the next day, he tells us: "This day almost everybody had seen the animal which the pigeon-shooters had brought an account of the day before; and one of the seamen, who had been rambling in the woods, told us on his return that he verily believed he had seen the devil. We naturally inquired in what form he had appeared, and his answer was, says John, 'As large as a one-gallon keg, and very like it; he had horns and wings, yet he crept so slowly through the grass that, if I had not been *afeared*, I might have touched him.' This formidable apparition we afterward, however, discovered to have been a bat (A FLYING FOX). . . . Early the next day," Captain Cook continues, "as I was walking in the morning, at a little distance from the ship, I saw myself one of the animals which had been described; it was of a light mouse-color, and in size and shape very much resembling a greyhound; it had a long tail also, which it carried like a greyhound; and I should have taken it for a wild-dog if, instead of running, it had not leaped like a hare or deer." Mr. Banks also had an imperfect view of this animal, and was of opinion that its species was hitherto unknown. The work exhibits an excellent figure of the animal. Again, on Sunday, July 8th, being still in Endeavor River, Captain Cook tells us that some of the crew "set out, with the first dawn, in search of game, and in a walk of many miles they saw four animals of the same kind, two of which Mr. Banks's greyhound fairly chased; but they threw him out at a great distance, by leaping over the long, thick grass, which prevented his running. This animal was observed not to run upon four legs, but to bound or leap forward upon two, like the jerboa." Finally, on Saturday, July 14th, "Mr. Gore, who went out with his gun, had the good fortune to kill one of these animals which had been so much the subject of our speculation;" adding, "This animal is called by the natives *kanguroo*. The next day (Sunday, July 15th) our kanguroo was dressed for dinner, and proved most excellent meat."

Such is the earliest notice of this creature's observation by Englishmen; but Cornelius de Bruins, a Dutch traveler, saw,[1] as early as 1711, specimens of a species (now named after him, *Macropus Brunii*),

[1] *See* Cornelis de Bruins, "Reizen over Moskovie, door Persie en Indie." Amsterdam, 1714, p. 374, Fig. 213.

which he called *Filander*, and which were kept in captivity in a garden at Batavia. A very fair representation of the animal is given—one showing the aperture of the pouch. This species was, moreover, described both by Pallas[1] and by Schreber.[2]

It is not improbable, however, that kangaroos were seen by the earlier explorers of the western coast of Australia; and it may be that it is one of these animals which was referred to by Dampier, when he tells us that on August 12, 1699, "two or three of my seamen saw creatures not unlike wolves, but so lean that they looked like mere skeletons."

Having now learned something of the structure, habits, and history of the kangaroo, we may proceed to consider its zoölogical, geographical, and geological relations, in order to arrive at the best answer we may to our initial question, "What is a kangaroo?"

First, as to its zoölogical relations: and here it is necessary to recall to mind certain leading facts of zoölogical classification, in order that we may be better able to see with what creatures the kangaroo is, in various degrees, allied.

The whole animal population of the globe is spoken of under the fanciful term, the "animal kingdom," in contrast with the world of plants, or "vegetable kingdom."

The animal kingdom is divided into certain great groups, each of which is called a sub-kingdom; and one, the highest of these sub-kingdoms (that to which we ourselves belong), bears the name *vertebrata*, and it includes all beasts, birds, reptiles, and fishes; and the name refers to the series of bone called *vertebræ*, of which the back-bone or spinal column (and all *vertebrata have* a spinal column) is generally made up.

Each sub-kingdom is made up of subordinate groups, termed classes; and thus the vertebrate sub-kingdom is made up of the *class* of beasts or *Mammalia* (so called because they suckle their young), the class of birds, and other classes.

Each class is made up of subordinate groups, termed *orders;* each order is further subdivided into *families;* each family is made up of *genera;* while every genus comprises one, few, or many species.

In considering the zoölogical relations of the kangaroo, we have then to consider the relations borne by its genera to the other genera of its family, the relations borne by its family to the other families of its order, and finally the relations borne by its order to the other orders of its class (the *Mammalia*)—that class which includes within it all other beasts whatever, and also man.

In the first place, it may be observed, there are many species of kangaroos, arranged in some four genera; but the true kangaroos form a genus, *Macropus*, which is very nearly allied to the three other

[1] Pallas, "Act. Acad. Sc. Petrop.," 1777, part ii., p. 299, tab. 4, Figs. 4 and 5.

[2] Schreber, "Sangth.," iii., p. 551, pl. 153, 1778.

genera. 2. *Dorcopsis*, with a very large first back tooth. 3. The *tree kangaroos* (*Dendrolagus*), which frequent the more horizontal branches of trees, have the fore-limbs but little shorter than the hind-limbs, and inhabit New Guinea; 4. The *rat-kangaroos* (*Hypsiprymnus*), which have the first upper grinding-tooth large, compressed, and with vertical grooves.

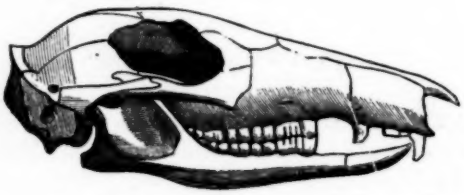


FIG. 6.—SKULL OF A RAT-KANGAROO (*Hypsiprymnus*).

These four genera together constitute the kangaroo's FAMILY, the *Macropodidæ*, the species of which all inhabit Australia and the islands adjacent, but are found nowhere else in the world.

The species agree in having—

1. The second and third toes slender and united in a common fold of skin.
2. The hind-limbs longer than the fore-limbs.
3. No inner *metatarsal* bone.
4. All the toes of each fore-foot provided with claws.
5. Total number of incisors only $\frac{6}{6}$.

These five characters are common to the group, and do not coexist in any other animals. They form, therefore, the distinguishing CHARACTERS of the kangaroo's family. This family, *Macropodidæ*, is one of the six other families which, together with it, make up that much larger group, the kangaroo's ORDER. As was just said, to understand what a kangaroo is, we must know "what are the relations borne by his *family* to the other families of its order;" and accordingly it is needful for our purpose to take at least a cursory view of those other families.

There is a small animal, called a *bandicoot* (Fig. 7), which, in external appearance, differs very plainly from the kangaroo, but resembles it in having the hind-limbs longer than the fore-limbs, and also in the form of its hind-feet, which present a kangaroo structure, but not carried out to such an extreme degree as in the kangaroo, and therefore approximating more to the normal type of foot, there being a rudimentary inner toe and a less preponderant fourth toe; the second and third toes, however, are still very small, and bound together by skin down to the nails. In the fore-foot, on the contrary, there is a deficiency, the outer toes being nailless or wanting. The cutting-teeth are more numerous, these being I $\frac{1}{3}$.

This little creature is an example of others, forming the family

Peramelidæ—a family made up of creatures none of which much exceed the hare in size, and which, instead of feeding on vegetable substances (as do the kangaroos), eat insects, for which food they are well adapted by the sharp points and ridges which may be seen on their back teeth.

Fig. 7.—Long-nosed Bandicoot (*Perameles*).

One member of this family, *Chœropus* (Fig. 8), is very exceptional in the structure of its hind-feet, which out-kangaroo the kangaroo in the

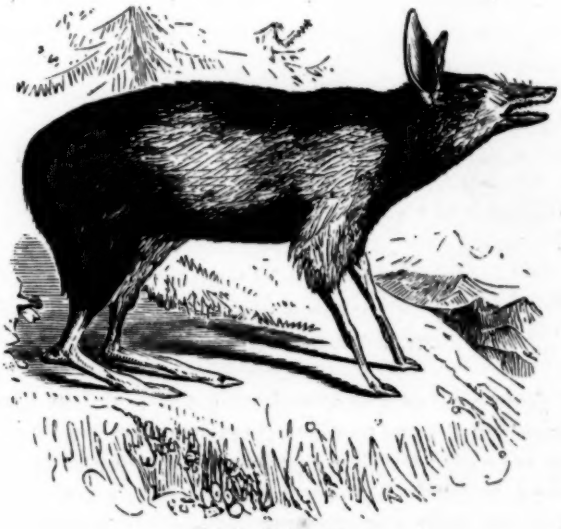


Fig. 8.—Chæropus.

minuteness of all the toes but the fourth, upon which alone the creature walks, while its front-feet are each reduced to two functional digits.

No other known beast besides walks upon a single toe in each hind-foot, save the horse family (horses, asses, and zebras), and they walk upon a different one, namely, that which answers to our middle-toe, while *Chæropus* walks on the next outer one or fourth. No known beast besides *Chæropus* walks upon two toes in each foot, save hoofed creatures, such as the ruminants and their allies; but in them it is the third and fourth toes that are used, while in *Chæropus* it is the second and third toes.

Another animal, called a phalanger (of the genus *Phalangista*), is a type of a third family of the kangaroo's order, the *Phalangistidæ*, a family made up of creatures which live in trees and are nocturnal in their habits, feeding upon fruits and leaves. Here we find the limbs of nearly equal length. Once more we have I $\frac{2}{2}$, and we still have the second and third toes united in a common fold of skin; but the innermost toe (that answering to *our* great-toe) is not only largely developed, but is like that of the apes, directed outward, and capable of being opposed to the other toes, as our thumb can be opposed to our fingers.

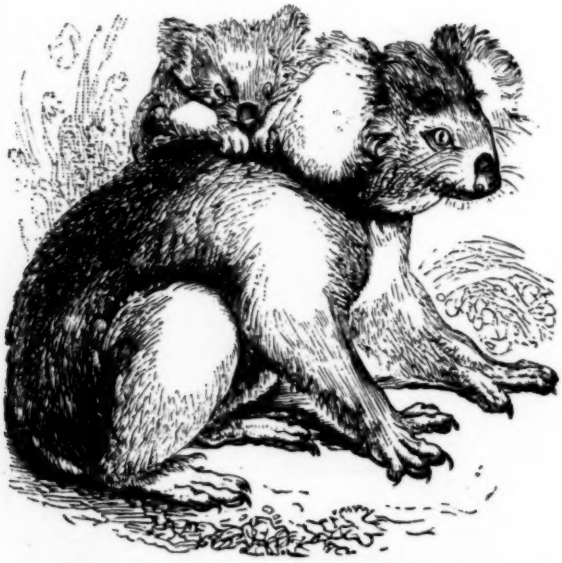


FIG. 9.—THE KOALA (*Phascolarctus*).

Some of these creatures have prehensile tails. Others have the skin of the flanks enlarged so as to serve them as a parachute in their leaps, whence they are called "flying opossums," just as squirrels, similarly provided, are called "flying" squirrels.

There are two very aberrant members of this family. One, the koala, Fig. 9 (*Phascolarctus*), called the native bear or native sloth, is devoid of any tail.

The other, *Tarsipes*, but little bigger than a mouse, has a long and

pointed muzzle, and its teeth are reduced to minute pointed processes, few in number, $\frac{6-6}{5-5}$, situated far apart in each jaw.

FIG. 10.—CUSCUS ORIENTALIS.

The genus *Cuscus*, closely allied to *Phalangista*, is found in New Guinea and the adjacent islands to Timor (Fig. 10).

FIG. 11.—THE WOMBAT (*Phascolomys*).

Another animal, the wombat, Fig. 11 (*Phascolomys*), forms by itself a distinct family, *Phascolomyidæ*. It is a burrowing nocturnal

animal, about the size of a badger, with rudimentary tail and peculiar feet and teeth.

We still find the second and third toes bound together, limbs of equal length, and all the five toes of the fore-foot with claws (as in the last family), but the great-toe is represented by a small tubercle, while the cutting teeth are $\frac{2}{2}$, growing from persistent pulp through life, as in rats, squirrels, and Guinea-pigs (Fig. 12).

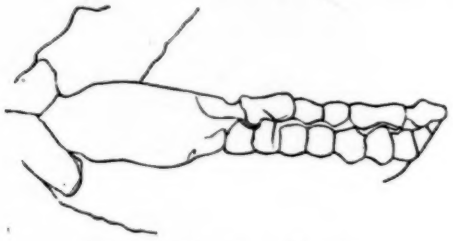


FIG. 12.—TEETH OF THE WOMBAT.

We may now pass to a very different family of animals belonging to the kangaroo's order. We pass, namely, to the *Dasyuridæ*, or family of the native cat, wolf, and devil, so named from their predatory or fierce nature. They have well-developed eye-teeth (or canines), and back teeth with sharp cutting blades, or bristling with prickly points. The second and third toes are no longer bound together; and while there are five toes with claws to each fore-foot, the great-toe is either absent altogether or small. The cutting teeth, Fig. 13, are $\frac{6}{6}$,

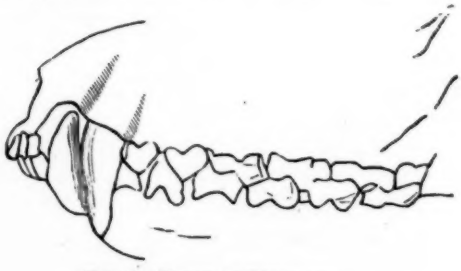


FIG. 13.—TEETH OF DASYURUS.

and the tail is long and clothed with hair throughout. Some of these animals are elegantly colored and marked, and all live on animal food. This form (belonging to the typical genus *Dasyurus*, which gives its name to the family) may be taken as a type; but two others merit notice.

The first of these is *Myrmecobius*, Fig. 14, from Western Australia, remarkable for its number of back teeth, $\frac{8-8}{9-9}$, and for certain geographical and zoölogical relations, to be shortly referred to. With respect to this creature, Mr. Gilbert has told us:

"I have seen a good deal of this beautiful little animal. It appears very much like a squirrel when running on the ground, which it does in successive leaps, with its tail a little elevated, every now and then raising its body, and resting on its hind-feet. When alarmed, it generally takes to a dead tree lying on the ground, and before entering

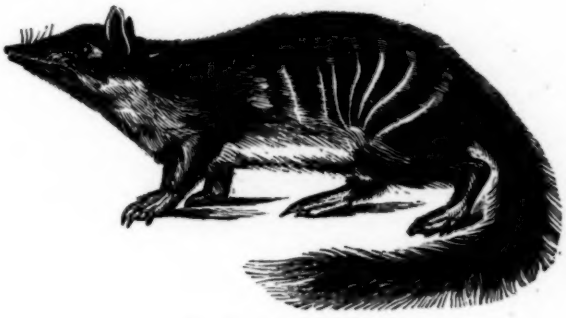


Fig. 14.—Myrmecobius.

the hollow invariably raises itself on its hind-feet, to ascertain the reality of approaching danger. In this kind of retreat it is easily captured, and when caught is so harmless and tame as scarcely to make any resistance, and never attempts to bite. When it has no chance of escaping from its place of refuge, it utters a sort of half-smothered grunt, apparently produced by a succession of hard breathings."

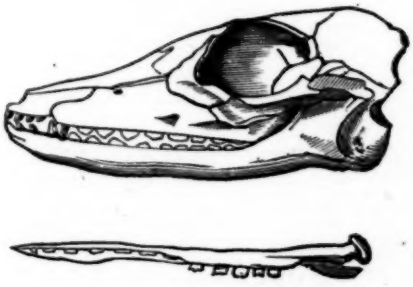


Fig. 15.—Skull of Myrmecobius.

The other member of the family *Dasyuridæ*, to which I call the reader's attention, is a very different animal from the *Myrmecobius*. I refer to the largest of the predatory members of the kangaroo's order; namely, to the Tasmanian wolf. It is about the size of the animal after which it is named, and it is marked across the loins with tiger-like, black bands (Fig. 16). It is only found in the island of Tasmania, and will probably very soon become altogether extinct, on account of its destructiveness to the sheep of the colonists. Its teeth have considerable resemblance to those of the dog, and it differs from

all other members of the kangaroo's order, in that *mere cartilages* represent those marsupial bones which every other member of the order unquestionably possesses.

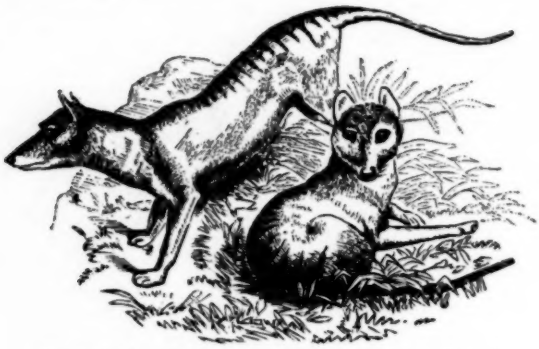


Fig. 16.—Tasmanian Wolf (*Thalacinus Cynocephalus*).

The last family of the kangaroo's order consists of the true opossum, which (unlike all the animals we have as yet passed in review) inhabits not the Australian region, but America only.

These creatures vary in size from that of the cat to that of the rat.

They are called *Didelphidæ*, and agree with the *Dasyuridæ* in having well-developed canine teeth and cutting back teeth (Fig. 17); in

Fig. 17.—Teeth of Opossum (*Didelphys*).

having the second and third toes free, and five toes to the fore-foot. But they differ in that—

1. Cutting-teeth $\frac{1}{3}^{9}$ (more than in any other animal).
2. A large opposable great-toe.
3. A tail, naked (like that of the rat) and prehensile.

One of them is aquatic in its habits and web-footed. Such are the very varied forms which compose the six families which together make up the kangaroo's order, and such are the relations borne by the kangaroo's family to the other families of the kangaroo's order.

But, to obtain a clear conception of the kangaroo, we must not rest content with a knowledge of its order considered by itself. But we must endeavor to learn the relation of its order to the other orders of that highest class of animals to which the kangaroo and we ourselves both belong, namely, the class *Mammalia*, which class, with the

other classes, birds, reptiles, and fishes together, makes up the backboned or *vertebrate* primary division of the whole animal kingdom.

What, then, is the relation of the kangaroo's order—the MARSUPIALIA—to the other orders of the class Mammalia?

Now, these orders are:

1. The order which contains man and apes.
2. That of the bats.
3. That of the mole, shrew, hedgehog, and their allies—all *insectivorous.*
4. That of the dog, cat, weasel, and bear—all *carnivorous.*
5. That of the gnawing animals, such as the rat, squirrel, jerboa, and guinea-pig—all with cutting-teeth $\frac{2}{2}$, with permanent pulps. They are called Rodents.
6. The order containing the sloths.
7. That of the grazing, hoofed quadrupeds—deer, antelopes, and their allies.

Besides three orders of aquatic beasts (seals, whales, and the manatee order), with which we need not be now further concerned.

FIG. 18.—THE YAPOCK (*Chironectes*).

Now, in the first place, very noticeable is the much greater diversity of structure found in the kangaroo's order than in any other order of mammals. While each of the *latter* is of one predominate type of structure and habit, we have found in the marsupials the greatest diversity in both.

Some marsupials are, we have seen, arboreal, some are burrowing, some flit through the air, while others range over and graze upon grassy plains. Some feed on vegetable food only, others are as exclu-

sively insectivorous or carnivorous, and their teeth vary much in number and structure. Certain of my readers may wonder that such diverse forms should be thus grouped together, apart from the other mammals. At first sight it might seem more natural to place together *flying opossums* with *flying squirrels;* the *native sloth* with the *true sloth;* the *dog* and *cat-like opossums* with the *true dogs* and *cats;* and, lastly, the *insectivorous marsupials* with the *other insectivora.*

As to the kangaroos themselves, they might be considered as approximating in one respect to the Ruminants, in another to the Rodents.

We have seen that even in Captain Cook's time its resemblance to the jerboa forced itself into notice. And, indeed, in this jerboa (and its first cousin, the *alactaga*) we have the same or even a relatively greater length of hind-limb and tail, and we have the same jumping mode of progression.

Again, in the little jumping insectivorous mammal, the shrew (*Macroscelides*), we meet with excessively long hind-limbs and a jumping habit. More than this: if we examine its teeth, we find both in the upper cutting teeth and in the back teeth great resemblance to those of the kangaroo. And yet there is no real affinity between the kangaroo and such creatures, any more than there is between a non-marsupial truly carnivorous beast and a marsupial carnivore. Indeed, both myself and my readers are far more like the jerboa or weasel than either of the latter is like to any marsupial animal.

The fact is, that all these so varied marsupial forms of life possess in common certain highly-important characters, by which they differ from all other mammals. These characters, however, mainly relate to the structure of their reproductive organs, and could not be here detailed without a long preliminary anatomical explanation; but, as to the great importance of these characters, naturalists are agreed.

Among the characters which serve to distinguish the marsupials, there are two to which I have already called attention in describing the kangaroo; namely, the marsupial bones and the inflected angle of the lower jaw.

Every mammal which has marsupial bones has the angle of its jaw inflected, or else has no angle to its jaw at all; while every animal which has both marsupial bones and an inflected jaw-angle possesses also those special characters of the reproductive system which distinguish the marsupials from all other mammals.

Thus it is clear we have at least two great groups of mammals. One of them—the non-marsupials—contains man; the apes; bats; hedgehog-like beasts (shrews, moles, etc.); cats, dogs, bears, etc.; hoofed beasts; edentates; rodents, and also the aquatic mammals. And this great group, containing so many orders, is named MONODELPHIA.

The other great groups consist of all the marsupials, and no others. It consists, therefore, of the single order, *Marsupialia*, and is called DIDELPHIA.

Another group of mammals is made up of two genera only—the duck-billed platypus, or *Ornithorhynchus*, and the *Echidna*, two most interesting forms, but which cannot be further noticed here. They form, by themselves, a theme amply sufficient for an article, or even half a dozen articles.

As to its zoölogical relations, then, we may say that *the kangaroo is a peculiarly modified form of a most varied order of mammals* (*the* MARSUPIALS), *which differ from all ordinary beasts* (and at the same time differ from man) *by very important anatomical and physiological characters, the sign of the presence of which is the coexistence of marsupial bones with an inflected angle of the lower jaw.*

We may now proceed to the next subject of inquiry, and consider the space relations (that is, the geographical distribution) of the kangaroo, its family, and order. I have already incidentally mentioned some countries where marsupials are found, but all of those were more or less remote. To find living, in a state of nature, any member of the kangaroo's order, we must at least cross the Atlantic.

When America was discovered by the Spaniards, among the animals found there, and afterward brought over to Europe, were *opossums*, properly so called—marsupials, of the family *Didelphidæ*, which extend over the American Continent, from the United States to the far South. These creatures were the first to make known to Europeans[1] that habit of sheltering the young in a pouch which exists in the kangaroo, and which habit has given the name *Marsupialia* to the whole order. But, though this habit was duly noted, it is not strange that (being the only pouched forms then known) the value of the peculiarity should have been under-estimated. It is not strange that they should have been regarded as merely a new kind of ordinary flesh-eating beasts, since in the more obvious characters of teeth and general form they largely resembled such beasts. Accordingly even the great Cuvier, in the first edition of his "Règne Animal," made them a mere subdivision of his great order of flesh-eating mammals.

But, to find any other member of the kangaroo's order (besides the *Didelphidæ*), in a state of nature, we must go much farther than merely across the Atlantic; namely, to Australia or the islands adjacent to it, including that enormous and unexplored island, New Guinea, which has recently attracted public attention through the published travels of a modern Baron Munchausen.

To return, however, to our subject. To find marsupials at all, we

[1] The following are some among the earlier notices of these animals: "Histoire d'un Voyage fait en la Terre du Brésil," par Jean de Léry, Paris, 1578, p. 156. Hernande's "Hist. Mex.," p. 330, 1626. "Histoire Naturelle des Antilles," Rotterdam, 1658. "Anatomy of an Opossum," Tyson, Phil. Trans., 1698.

have, as we have seen, to go to the New World. To find nearer allies of the kangaroo, we must go to the *newest* world, Australia; *newest* because, if America merited the title of *new* from its new natural productions as well as its new discovery, Australia may well claim the superlative epithet on both accounts. We have found an indication, in the name Botany Bay, of the interest excited in the mind of Sir Joseph Banks by the new plants as well as by the new animals of Australia. And, indeed, its plants and animals do differ far more from those of the New World (America) than do those of America from those of the Old World.

Marsupials, in fact, are separated off from the rest of their class —from the great bulk of mammals—the *Monodelphia*—no less by their geographical limits than by their peculiarities of anatomical structure.

And these geographical limits are at the same time the limits of many groups of animals and plants, so that we have an animal population (or fauna) and a vegetable population (or flora) which are characteristic of what is called the Australian region—the Australian *region*, because the Australian forms of life are spread not only over Australia and Tasmania, but over New Guinea and the Moluccas, extending as far northwest as the island of *Lombok*, while marsupials themselves extend to *Timor*.

In India, the Malay Peninsula, and the great islands of the Indian Archipelago, we have another and a very different fauna and flora—those, namely, of the Indian region, and Indian forms of life extend downward southeast as far as the island of Bali. Now, Bali is separated from Lombok by a strait of but fifteen miles in width. But that little channel is the boundary-line between these two great regions—the Australian and the Indian. The great Indian fauna advances to its western margin, while the Australian fauna stops short at its eastern margin.

The zoölogical line of demarkation which passes through these straits is called "Wallace's line," because its discovery is due to the labors of that illustrious naturalist, that courageous, persevering explorer, and most trustworthy observer, Alfred Wallace, a perusal of whose works I cordially recommend to my readers, since the charm of their style is as remarkable as is the sterling value of their contents. Mr. Wallace pointed out that not only as regards beasts (with which we are concerned to-day), but that also as regards birds, these regions are sharply limited. "Australia has," he says, "no woodpeckers, no pheasants—families which exist in every other part of the world; but instead of them it has the mound-making brush-turkeys, the honey-suckers, the cockatoos, and the brush-tongued lories, which are found nowhere else upon the globe."

All these striking peculiarities are found also in those islands which form the Australian division of the archipelago, while in those

islands which belong to its Indian division these Australian birds have no place.

On passing from the island of Bali to that of Lombok, we cross the division between the two. "In Bali," he tells us, "we have barbets, fruit-thrushes, and woodpeckers, while in Lombok these are seen no more; but we have abundance of cockatoos, honeysuckers, and brush-turkeys, which are equally unknown in Bali, or any island farther west."

As to our second point, then—the geographical relations of the kangaroo—we may say that the *kangaroo is one of an order of animals confined to the Australian region and America, the great bulk of which order, including the kangaroo's own family*, MACROPODIDÆ, *is strictly confined to the Australian region.* We may further add that in the Australian region ordinary beasts (*Monodelphia*) are entirely absent, save some bats and a rat or two, and the wild-dog or dingo, which was probably introduced there by man himself.

There only remains, then, for us to inquire, lastly, what relations with past time may be found to exist on the part of the kangaroo's order or of the kangaroo itself. Now, in fact, these relations are of considerable interest. I have spoken of Australia as, what in one sense it certainly is, the *newest world*, and yet *the oldest world* would, in truth, be an apter title for the Australian region.

In these days we hear much of "survivals," as the two buttons behind our frock-coats are "survivals" of the extinct sword-belt they once supported, and the "Oh, yes! oh, yes! oh, yes!" of the town-crier is a "survival" of the former legal and courtly predominance of the French language among us. Well, in Australia we have to-day a magnificent case of zoölogical survival on the largest scale. There, as has already been said, we find living the little *Myrmecobius*, which represents before our eyes a creature living in the flesh to-day, which is like other creatures which once lived here in England, and which have left their relics in the Stonesfield oolite, the deposition of which is separated from our own age by an abyss of past time not to be expressed by thousands of years, but only to be indicated in geological language as the Mesozoic period—the middle of the secondary rocks.

But Australia presents us with a yet more interesting case of "survival." Certain fish-teeth had from time to time been found in deposits of oolitic and triassic date, and the unknown creature to which they once belonged had received the name of *Ceratodus*. Only five years ago this animal, supposed to have been extinct for untold ages, was found still living in Queensland, where it goes by the name of "flat-head." It is a fish of somewhat amphibious habits, as at night it leaves the brackish streams it inhabits, and wanders among the reeds and rushes of the adjacent flats. The anatomy of this animal has been carefully described for us by Dr. Günther.

We have, then, in Australia what may be termed a triassic land,

still showing us in life to-day the more or less modified representations of forms which elsewhere have long since passed away from among us, leaving but rare and scattered fragments—relics "sealed within the iron hills."

No member of the Australian families of the kangaroo's order has left its relics in European strata more recent than the secondary rocks. But the American family, *Didelphidæ*, is represented in the earliest Tertiary period by the remains of an American form (a true opossum) having been found by Cuvier in the quarries of Montmartre. He first discovered a lower jaw, and, from its inflected angle, concluded that it belonged to a marsupial animal, and that therefore marsupial bones were hidden in the matrix. Accordingly he predicted that such bones would be found; and, proceeding to remove the enveloping deposit with the greatest care, he laid bare before the admiring eyes of the bystanders the proof of the correctness of his prediction. It is noteworthy, however, that, had this fossil been that of an animal like the Tasmanian wolf, he would have been disappointed, as, though marsupial, it has, as has been already said, not marsupial *bones*, but *cartilages*.

But relics of creatures more closely allied to the kangaroo existed in times ancient historically, though, geologically speaking, very recent. Just as in the recent deposits of South America we find the bones of huge beasts, first cousins to the sloths and armadilloes which live there now, so in Australia there lived beasts having the more essential structural characters of the kangaroo, yet of the bulk of the rhinoceros. Their bones and teeth have been found in the tertiary deposits of Australia. They have been described by Prof. Owen, and are now to be seen preserved in the British Museum and that of the Royal College of Surgeons. It may be that other fossil forms of the middle mesozoic or even of triassic times may, so some believe, have belonged to creatures of the kangaroo's family; but at least there is no doubt that such existed in times of post-tertiary date.

As to our third point—the geological relations of the kangaroo—we may say, then, that "*the kangaroo is one of an order of animals which ranged over the Northern Hemisphere in triassic and oolitic times, one exceptional family lingering in Europe to the Eocene period, and in America to the present day. That the kangaroo itself is a form certainly become fossil in its own region, where, in times geologically recent, creatures allied to it, but of vastly greater bulk, frequented the Australian plains.*"

We may now, then, proceed to answer finally the question, "*What is a kangaroo?*" We may do so because the meaning of the technical terms in which the answer must necessarily be expressed (if not of undue length) has been now explained, as far as space has allowed.

We may say, then, that "*the kangaroo is a didelphous (or marsupial) mammal, of the family* MACROPODIDÆ; *an inhabitant of the*

Australian region, and connected, as respects its order, with triassic times, and possibly even as regards its family also, though certainly (as regards the latter) with the time of the post-tertiary geological deposits."

We have seen what are didelphous and what are monadelphous mammals; what are the respective values of the terms "order," "family," and "genus," and also in what respect the kangaroo differs from the other families of the marsupial order. We have also become acquainted with the distribution of organic life now and with the inter-relations of different geological strata, as far as those phenomena of space and of time concern our immediate subject.

By becoming acquainted with these matters, and by no other way, is it possible to give an intelligent answer to the question, "*What is a kangaroo?*"—*Popular Science Review.*

LIFE IN GREENLAND.

THE Danish settlements in Greenland date from the year 1721, when a colony was established at Godthaab, in latitude 64° north. The country had been visited and colonies settled there as early as the tenth century by Icelanders; but these Icelandic colonies were utterly destroyed, probably by the pestilence known as the "black-death" in the fourteenth century, or early in the fifteenth. The present Danish settlements are all situated on the west coast, and contain about 10,000 inhabitants, all Esquimaux with the exception of a few hundred, who are Danes. The region of Disco Bay may be regarded as the type of the entire western coast of Greenland. The aspects of Nature and the conditions of human life, as presented in this region, are graphically portrayed by Dr. Robert Brown, F. R. G. S., in the *Geographical Magazine*, and in the following pages we purpose to epitomize, for the benefit of our readers, the account given by this very competent observer. Dr. Brown, we would add, is probably the highest living authority on all scientific questions connected with Greenland; he has written a number of memoirs upon the geology, meteorology, etc., of the country, which are held in the very highest esteem by men of science.

Disco Bay is situated between the parallels of about 68° and 70° north latitude. On the west lies Disco Island, and on the east Greenland. Nowhere are the cliffs high, and the southern shore is in general flat and uninteresting. About Christianshaab (latitude 69°), and farther to the north, the shores are backed by bare rocky hills of about 1,000 or 1,200 feet—rounded knolls of gneiss, ice-shaven and worn. Between these higher grounds run birch and willow-covered

mossy valleys, bright with running streams and waterfalls during the brief arctic summer. Everywhere are indubitable signs that the extensive *mer de glace*, which is believed to cover the whole interior of Greenland, once covered at least the greater part of what is now the uncovered or "fast-land" of the Danes. The ice is again beginning to encroach on the land, and everywhere in this vicinity there are proofs of a gradual subsidence of the ground.

From the fossil remains of numerous land-plants and a few insects found in the Miocene beds of Disco Island, it appears that in comparatively recent times a luxuriant vegetation, somewhat similar in character to that of California or the Southern United States, flourished in these arctic wastes. Luxuriant evergreen-oaks, magnolias, and sequoias, grew where now is found only the dwarf-willow, creeping along the ground with a stem not over half an inch in diameter. Among the fossil trees of Greenland, Prof. Heer has discovered three distinct species of sequoia, nine of oak, four of which were evergreen, like the Italian oak, two beeches, a chestnut, two planes, and a walnut. "Besides these," writes Prof. Heer, "American species, such as the magnolias, sassafrasses, and liquidambars, were represented there; and the characters of the ebony-tree are to be distinguished in two of the species. The hazel, the sumach, the buckthorn, and the holly, the guelder-rose, and the white, probably formed the thickets at the borders of the woods; while the vine, the ivy, and the sarsaparilla, climbed over the trees of the virgin forest, and adorned them with garlands. In the shadow of the wood grew a profusion of ferns, which covered the soil with their elegant fronds. The insects which gave animation to these solitudes are not all lost. The impressions of these which have reached us show that *Chrysomelas* and *Castilidæ* enjoyed themselves in the sun, and large *Trogsitæ* pierced the bark of the trees, while charming *Cicadellæ* leaped about among the herbage." In all, about 167 species of Miocene plants have been discovered in Greenland.

The coal found on Disco Island is, like all tertiary lignites, of poor quality, but yet, when mixed with English coal, it forms a good fuel for household and even for steaming purposes. It is mined to a small extent for the use of the settlements around the bay. Soapstone is found in some places in the primitive rocks, on the southern shores of Disco Bay; it was at one time extensively employed by the Esquimaux for making various domestic utensils, but is now much less used, owing to the introduction of vessels of iron, copper, and tin. There is no other economic mineral, cryolite being only found in one locality, Arsut Fiord, in South Greenland.

In the winter the cold is extreme in the region of Disco Bay, and the ground is generally thickly covered with snow from September till May or early June. During this period the whole sea is covered with ice, and the Danes and Esquimaux visit from settlement to settle-

ment in sledges drawn by dogs. During the summer, under the four months of continual daylight, the snow soon melts over the lower lands, and the heat is often extreme. Mosquitoes are troublesome, and, there being no shelter from the rays of the sun reflected from the snow, ice, and bare rocks, traveling is frequently attended with great discomfort. The day may be bright and sunny in the morning, and in the evening snow, sleet, and all the concomitants of spring or winter. During the short summer season vegetation springs up apace and soon comes to maturity. In September the weather is uncertain and the nights are very dark and cold.

The trade of Danish Greenland is a strict crown monopoly, and is administered by government officials solely for the benefit of the natives. The principle adopted is to buy the natives' blubber, skins, ivory, etc., at a low price and to sell to them articles of European manufacture which are necessary to their comfort at an equally low figure; coffee and other luxuries are sold at a good profit. The surplus is credited to each district, and expended for the public good, by the little local parliaments (Partisoks) of the districts, the members of which (partisæts) are elected by universal suffrage. The settlements are known as colonies, and each is presided over by a "colonibestyrer" (*best man in the colony*). The other notables of the colony are the colonibestyrer's assistant, the cooper, the carpenter, and, if the settlement is large, the Lutheran parson, and the schoolmaster—the latter generally an educated native. The most exciting event in the settlements is the arrival of the annual ship from Copenhagen. Pianos are not unknown in the houses of the Danish officials, and the Tauchnitz edition of the best English authors is to be found in the "governor's" house.

The Danish Government treat the natives with the most paternal care. No spirits are allowed to be sold to them, schools are provided, and altogether the rule of the little northern kingdom is productive of very good results. Theft is practically unknown in Danish Greenland.

The vegetation around Disco Bay is, during the brief summer, rather luxuriant; the rocks are bright with mosses, and gayly-colored flowers peep out from the crannies. In the Upernivik district the birch is said to grow high enough in localities to cover the reindeer. Such giant shrubs are looked upon with pride by the natives. They take visitors to see them, and point to these extraordinary specimens of vegetation with an air as of "See this and die!"

Hunting and fishing form the sole occupation of those natives who are not in the government service. The white bear is almost extinct in this region; farther north they are more numerous. The arctic fox is common. The native dog is threatened with extermination by a peculiar disease which first appeared in Greenland a few years ago. The cat has become domesticated. The mouse and rat are regularly

introduced every summer with the European ships, but rarely survive the winter. The arctic hare is common. The reindeer is now so rare in the vicinity of Disco Bay that few natives care to go hunting it. The seals are the main staple of the Esquimaux hunt. Large numbers are killed, both in summer and winter, but chiefly on the ice-fields during the latter season. The right-whale is now only a rare visitor. The white whale and the narwhal are often killed.

All the more common arctic birds visit Disco Bay in the summer, but, with the exception of the ptarmigan and some of the raptorial birds, they migrate during the winter. There are no reptiles in Greenland, but the salt-water fishes are numerous. Shark-fishing forms a considerable branch of industry. The kalleraglek, or small halibut, is caught in Disco Bay; among the Danes it forms a favorite dish, when sliced and dried. About six species of *Salmo* are found in Greenland. Both the trout and the salmon are excellent, though they have a thick layer of fat beneath the skin. The marine invertebrata are numerous. Insect-life is poor; a few butterflies are seen during the summer months; some *Coleoptera*, a few *Diptera*, *Hymenoptera*, etc., go to make up the limited insect fauna of the region of Disco Bay.

SCIENCE AND RELIGION.[1]

By Rev. CHARLES F. DEEMS, D. D.

THIS recent cry of the "Conflict of Religion and Science" is fallacious, and mischievous to the interests of both science and religion; and would be most mournful if we did not believe that, in the very nature of things, it must be ephemeral. Its genesis is to be traced to the weak foolishness of some professors of religion, and to the weak wickedness of some professors of science. No man of powerful and healthy mind, who is devout, ever has the slightest apprehension that any advancement of science can shake the foundations of that faith which is necessary to salvation. No man of powerful and healthy mind, engaged in observing, recording, and classifying facts, and in searching among them for those identities and differences which point to principles and indicate laws, ever feels that he suffers any embarrassment or limitations in his studies by the most reverent love he can have for God as his Father, or the most tender sympathy he can have for man as his brother, or that hatred for sin which produces penitence, or that constant leaning of his heart on God which

[1] Extract from the opening address at the inauguration of Vanderbilt University, by Charles F. Deems, D. D., pastor of the Church of the Strangers, New York, October 4, 1875.

produces spiritual-mindedness, or that hope of a state of immortal holiness which has been the ideal of humanity in all ages.

All this dust about "the conflict" has been flung up by men of insufficient faith, who doubted the basis of their faith; or by men of insufficient science, who have mistaken theology or the Church for religion; or by unreasonable and wicked men, who have sought to pervert the teachings of science so as to silence the voice of conscience in themselves, or put God out of their thoughts, so that a sense of his eternal recognition of the eternal difference between right and wrong might not overawe their spirits in the indulgence of the lust of the flesh, the lust of the eye, and the pride of life. It may be profitable to discriminate these; and, if badges and flags have become mixed in this fray, it may be well to readjust our ensigns, so that foes shall strike at only foes.

It is, first of all, necessary to settle distinctly what science is, as well as what it is not; and also, what religion is, as well as what it is not.

We can all afford to agree upon the definition rendered by the only man who has been found in twenty-two centuries to add anything important to the imperial science of logic. Sir William Hamilton defines science as "a complement of cognitions, having in point of form the character of logical perfection, and in point of matter the character of real truth." Under the focal heat of a definition like this, much that claims to be science will be consumed. It is the fashion to intimate, if not to assert, that it is much more easy to become scientific than to become religious; that in one case a man is dealing with the real, in the other with the ideal; in the one case with the comprehensible, in the other with the incomprehensible; in the one case with that which is certain and exact, and in the other case with that which at best is only probable and indefinite.

There can be no doubt, among thoughtful men, of the great value of both science and religion. A thinker who is worth listening to is always misunderstood if it be supposed that he means to disparage either. An attempt to determine the limits of religion is no disparagement thereof, because all the most religious men who are accustomed to think are engaged in striving to settle those limits, in order that they may have advantage of the whole territory of religion on the one hand, and on the other may not take that as belonging to religion which belongs to something else.

Now, if Sir William Hamilton's definition is to be taken, we shall perceive that he represents science in its quality, in its quantity, and in its form. Cognition of something is necessary for science. Then, (1) the knowledge of things known must be true; (2) that knowledge must be full, and (3) it must be accurate; it must be in such form as to be most readily and successfully used by the logical understanding for purposes of thought.

This sets aside very much that has been called science, and, as it seems, perhaps nearly all that which has been the material used by those who have raised the most smoke over this "conflict" question.

"Guesses at truth" are valuable only as the pecking at a plastered wall, to find where a wooden beam runs, is useful; but a guess is not knowledge. A working hypothesis were not to be despised, although the student of science might feel quite sure in advance that when he had learned the truth in this department he would throw the hypothesis away. A working hypothesis, like a scaffold, is useful; but a scaffold is not a wall. Art is not science. Art deals with the appearances, science with the realities, of things. Art deals with the external, science with the internal, of a thing; art with the phenomenon, science with the *noumenon*. It must be the "*real* truth" which we know, and know truly.

Weak men on both sides have done much harm—the weak religionists by assuming, and the weak scientists by claiming, for guesses and hypotheses, the high character and full value of real truth. The guesses of both have collided in the air, and a real battle seemed impending; but it was only "guesses" which exploded—bubbles, not bombs; and it is never to be forgotten that a professor of religion has just as much right to guess as a professor of science, and the latter no more right than the former, although he may have more skill.

No man can abandon a real truth without degradation to his intellectual and moral nature; but Galileo, Kepler, and Newton, in their studies from time to time, employed and discarded theory after theory, until they reached that which was capable of demonstration. It was only that which took its place as science. In the case of Kepler, it is known what great labor he spent in attempting to represent the orbit of Mars by combinations of uniform circular motion. His working hypothesis was the old doctrine of epicyclic curves. But his great labor was not fruitless, as has been carelessly asserted. The theory was false, and therefore not a part of real science; but, working on it, he discovered that the orbit of Mars is an ellipse, and this led him to the first of his three great laws of planetary motion, and enabled him almost immediately to discover the second. Here was a great intellect employing as a working hypothesis a theory which has always been false, and now is demonstrably false. It was not science.

Now if, while scientific men are employing working hypotheses merely as such, men representing religion fly at them as if they were holding those hypotheses as science, or if men representing science do set forth these hypotheses as if they were real knowledge of truth, and proceed to defend them as such, then much harm is done in all directions.

In the first instance, the religious man shows an impatience which is irreligious. "He that believeth doth not make haste." It is unfair

to criticise any man while he is doing. Let him do what he will do; then criticise *the deed.* The artist has laid one pigment on his palette, and he is criticised before it is known what others he intends to mix with it, to procure what shade, to produce what effect. Wait until all the paint is on the canvas, and the artist has washed his brushes and drawn the curtain from his picture; then criticise *the picture.*

This impatient and weak criticism on the part of religious men is injurious to scientific progress, as well as to the progress of religion. For the latter, it makes the reputation of unfairness; for the former, it does one of two bad things: it obstructs free discussion among students of science, or pushes them into a foolish defiance of religion. Men must co-work with those of their own sphere of intellectual labors. They must publish guesses, conjectures, hypotheses, theories. Whatever comes into any mind must be examined by many minds. It may be true, it may be false; there must be no prejudgment. Now if, because our scientific men are discussing a new view, our religious men fly among them and disturb them by crying "Heresy!" "Infidelity!" "Atheism!" those students must take time to repel the charges, and thus their work be hurt. If let alone, they may soon abandon their false theory. Certainly, if a proposition in science be false, the students of science are the men likeliest to detect the falsehood, however unlikely they may be to discover the truth that is in religion. Nothing more quickly destroys an error than to attempt to establish it scientifically.

The premature cries of the religious against the scientific have also the effect of keeping a scientific error longer alive. Through sheer obstinacy the assailed will often hold a bad position, which, if not attacked, had been long ago abandoned. And we must have noticed that Nature seems quite as able to make scientific men obstinate as grace to do this same work for the saints.

No man should be charged with being an atheist who does not, in distinct terms, announce himself to be such; and in that case the world will believe him to be too pitiful a person to be worth assailing with hard words. But as you may drive a man away from you by representing him as your enemy, so a scientific man may be driven from the Christian faith, if convinced that the Christian faith stands in the way of free investigation and free discussion; or, he may hold on to the faith because he has brains enough to see that one may be most highly scientific and most humbly devout at the same time; but by persecution he may be compelled to withdraw from open communion with "those who profess and call themselves Christians." Then both parties lose—what neither can well afford to lose—the respect and help which each could give the other. When the son of a religious teacher turns to the works of a man whom he has heard that father denounce, and finds in any one page of those books more high religious thought than in a hundred of his father's commonplace dis-

courses, a sad state of feeling is produced, and many mistakes are likely to follow.

Sir William Hamilton's definition of science has for *genus* "a complement of cognitions," and for *differentia* "logical perfection of form," and "real truth of matter." The definition is a demand for a certain fullness. We can only conjecture, in the case of any particular science, how much knowledge such a man as Sir William Hamilton would regard as a "complement." But students of science do well to remind themselves that it is impossible to exceed, and very difficult to succeed, and the easiest thing imaginable to fall short. In other words, we have never been able to collect more material of knowledge than the plan of any temple of science could *work in*, and really did not demand for the completion of the structure, and that very few temples of science have been finished, even in the outline, while all the plain of thought is covered by ruins of buildings begun by thinkers, but unfinished for want of more knowledge. Even where there has been gathered a sufficient amount of knowledge to be wrought by the logical understanding into the form of a science, so that such a mind as Hamilton's would admit it as a science—i. e., a sufficient complement of cognitions of truths put in logical form—another age of labor, in other departments, would so shrink this science that, in order to hold its rank, it would have to *work in* the matter of more knowledge, and, to preserve its symmetry, be compelled to readjust its architectural outlines. In other words, what is science to one age may not be science to its successor, because that successor may perceive that, although its matter had the character of real truth, and its form the character of logical perfection, *as far as it went*, nevertheless, there were not enough cognitions; not enough, just because in the later age it was possible to obtain additional cognitions, which could not have been obtained earlier.

And, in point of fact, has not this been the history of each of the acknowledged sciences? And can any significance be assigned to Sir William Hamilton's definition without taking the word "complement" to mean *all the cognitions possible at the time?* Now, unless at one time men have more cognitions of any subject than at another time, one of two things must be true: either (1) no new phenomena will appear in that department, or (2) no abler observer will arise. But the history of the human mind in the past renders both suppositions highly improbable. If no new phenomena appear, we shall have observers abler than have existed, because, although it were granted that no fresh accessions of intellectual power came to the race, each new generation of observers would have increased ability, because each would have the aid of the instruments and methods of all predecessors. When we go back to consider the immense labor performed by Kepler in his investigations which led to his brilliant discoveries, we feel that if his nerves had given way under his labors, and domes-

tic troubles, and financial cares, or his industry had been just a little less tenacious, he would have failed in the prodigious calculations which led him to his brilliant discoveries, and gave science such a great propulsion. Just five years after the publication of Kepler's "New Astronomy" the Laird of Merchison published, in Scotland, his "*Mirifici Logarithmorum Canonis Descriptio.*" If Kepler had only had Napier's logarithms! But succeeding students have enjoyed this wonderful instrumental aid, and done great mental work with less draught on their vital energies.

The very facts, then, which make us proud of modern science should make scientific men very humble. It will be noticed that the most arrogant cultivators of science are those who are most ready to assail such religious men as are rigid, and hold that nothing can be added to or taken away from theology; and such scientific men make this assault on the assumption that physical sciences are fixed, certain, and exact. How ridiculous they make themselves, a review of the history of any science for the last fifty years would show. Is there any department of physical science in which a text-book used a quarter of a century ago would now be put into the hands of any student? The fact is that any man, who is careful of his reputation, has some trepidation in issuing a volume on science, lest the day his publishers announce his book the morning papers announce, also, a discovery which knocks the bottom out of all his arguments. This shows the great intellectual activity of the age—a matter to rejoice in, but it should also promote humility, and repress egotism in all well-ordered minds. There is, probably, no one thing known in its properties and accidents, in its relations to all abstract truths and concrete existence. No one thing is exactly and thoroughly known by any man, or by all men. Mr. Herbert Spencer well says: "Much of what we call science is not exact, and some of it, as physiology, can never become exact" ("Recent Discussions," p. 158). He might have made the remark with greater width, and no less truth, since every day accumulates proof that that department of our knowledge which we call the exact sciences holds an increasingly small proportion to the whole domain of science.

There is one important truth which seems often ignored, and which should frequently be brought to our attention, viz., that the propositions which embody our science are statements not of absolute truths, but of probabilities. Probabilities differ. There is that which is merely probable, and that which is more probable, and that which is still much more probable, and that which is so probable that our faculties cannot distinguish between this probability and absolute certainty; and so we act on it as if it were certain. But it is still only a "probability," and not a "certainty." It seems as though it would forever be impossible for us to determine how near a probability can approach a certainty without becoming identical with that certainty.

Is not all life a discipline of determining probabilities? It would seem that God intends that generally the certainties shall be known only to himself. He has probably shown us a very few certainties, more for the purpose of furnishing the idea than for any practical purpose, as absolute certainty is necessary for him, while probabilities are sufficient for us. All science is purely a classification of probabilities.

We do not *know* that the same result will follow the same act in its several repetitions, but *believe* that it will; and we believe it so firmly that if a professor had performed a successful experiment before a class in chemistry, he would not hesitate to repeat the experiment after a lapse of a quarter of a century. Scientific men are not infidels. Of no men may it be more truly said that they "walk by faith." They do not creep, they march. Their tread is on made ground, on probabilities; but they believe they shall be supported, and according to their faith so is it done unto them.

And no men better know than truly scientific men that this probability can never become certainty. In the wildest dreams of fanaticism—and there are fanatics in the laboratory, as there are in the sanctuary of God and in the temple of Mammon—it has never been believed that there shall come a man who shall know all things that are, all things that have been, all things that shall be, and all things that can be, in their properties, their attributes, and their relations. Until such a man shall arise, science must always be concerned with the cognition of that which is the real truth as to probabilities, or with probable cognitions of that which is not only real truth, but absolute truth. A scientific writer, then, when he states that any proposition has been "proved," or anything "shown," means that it has been proved probable to some minds, or shown to some—perhaps to all—intelligent persons as probable. If he have sense and modesty, he can mean no more, although he does not cumber his pages or his speech with the constant repetition of that which is to be presumed, even as a Christian in making his appointments does not always say *Deo volente*, because it is understood that a Christian is a man always seeking to do what he thinks to be the will of God, in submission to the providence of God.

A scientific man ridicules the idea of any religious man claiming to be "orthodox." It must be admitted to be ridiculous, just as ridiculous as would be the claim of a scientific man to absolute certainty and unchangeableness for science. The more truly religious a man is, the more humble he is; the more he sees the deep things of God, the more he sees the shallow things of himself. He claims nothing positively. He certainly does not make that most arrogant of all claims, the claim to the prerogative of infinite intelligence. There can exist only one Being in the universe who is positively and absolutely orthodox, and that is God. In religion, as in science, we walk

by faith; that is, we believe in the probabilities sufficiently to act upon them.

So far from any conflict being between science and religion, their bases are the same, their modes are similar, and their ends are identical, viz., what all life seems to be, that is, a discipline of faith.

It is not proper to despise knowledge, however gained: whether from the exercise of the logical understanding, or from consciousness, or from faith; and these are the three sources of knowledge. That which has been most undervalued is the chief of the three; that is, faith.

We *believe* before we acquire the habit of studying and analyzing our consciousness. We *believe* before we learn how to conduct the processes of our logical understanding.

We can have much knowledge by our faith without notice of our consciousness, and without exertion of our reasoning faculties; but we can have no knowledge without faith. We can learn nothing from our examination of any consciousness without faith in some principle of observation, comparison, and memory. We can acquire no knowledge by our logical understanding without faith in the laws of mental operations.

This last statement, if true, places all science on the same basis with religion. Although so familiar to many minds, we may take time to show that it is true.

For proof let us go to a science which is supposed to demonstrate all its propositions, and examine a student in geometry. We will not call him out on the immortal 47 : I of Euclid. We can learn all we need from a bright boy who has been studying Euclid a week. The following may represent our colloquy:

Q. Do you know how many right angles may be made by one straight line upon one side of another straight line?

A. Yes; two, and only two. Innumerable angles may be made by two straight lines so meeting, but the sum of all the possible angles will be two right angles.

Q. You say you know that. How do you know that you know it?

A. Because I can prove it. A man knows every proposition which he can demonstrate.

Q. Please prove it to me.

The student draws the well-known diagrams. If he follows Euclid, he begins with an argument like this:

A. There are obviously two angles made when a straight line stands on another straight line.

Q. My eyes show me that.

In answer he gives us the well-known demonstration of Euclid, to show that the sum of the two angles is equal to two right angles; and, when he has finished and reached the Q. E. D., he and his examiners *know* that this proposition is true, because he has proved it.

But when we examine his argument we find that he has made three unproved assumptions—namely: 1. That a thing cannot at the same time *be* and *not be;* 2. That if equals be added to equals, the wholes are equal; 3. That things which are equal to the same are equal to one another. It so happens that each of these propositions which he has assumed to be true is, if true, much more important than the proposition which he has proved. Let us point out these three assumptions to our bright student, and then resume our catechism.

Q. Could you possibly prove this proposition in geometry if any one of those three assumed propositions were not granted?

A. No.

Q. Then, if we deny these assumptions, can you prove them?

A. No; but can you deny them?

No, we cannot deny them, and cannot prove them; but we believe them, and therefore have granted them to you for argument, and know your proposition of the two right angles to be true, because you have proved it.

Now, here is the proposition which Euclid selected as the simplest of all demonstrable theorems of geometry, in the demonstration of which the logical understanding of a student cannot take the first step without the aid of faith.

From the student let us go to the master. We go to such a teacher as Euclid, and in the beginning he requires us to believe three propositions, without which there can be no geometry, but which have never been proved, and, in the nature of things, it would seem never could be proved—namely, that space is infinite in extent, that space is infinitely divisible, and that space is infinitely continuous. And we believe them, and use that faith as knowledge, and no more distrust it than we do the results of our logical understandings, and are obliged to admit that geometry lays its broad foundations on our faith.

Now, geometry is the science which treats of forms in their relations in space. The value of such a science for intellectual culture and practical life must be indescribably important, as might be shown in a million of instances. No form can exist without boundaries, no boundaries without lines, no line without points. The beginning of geometric knowledge, then, lies in knowing what a "point" is, the existence of forms depending, it is said, upon the motion of points. The first utterance of geometry, therefore, must be a definition of a point. And here it is: "A point is that which has no parts, or which has no magnitude." At the threshold of this science we meet with a mystery. "A point is"—then, it has existence—"is" what? In fact, in form, in substance, it is nothing. A logical definition requires that the *genus* and *differentia* shall be given. What is the *genus* of a "point?" Position, of course. Its *differentia* is plainly seen. It is distinguished from every thing else in this, that every thing else is

something somewhere, and a point is *nothing somewhere;* every thing HAS *some* characteristic, a point has *none.* A point is visible or invisible. Is it visible? Then we can see that which is without parts or magnitude. What is it we see when we do not see any part, do not see any magnitude? Is it substantial or ideal? If substantial, how do we detect its substantial existence? If ideal, how can an idea have motion, and by simple motion become a substantial existence? Are we not reduced to this? Ideals produce substantials, or invisible substantials, upon motion, produce visible substantials; or that which is necessary to matter—namely, form—owes its existence to that which is neither substantial nor ideal—to nothing, in fact. The entire and sublime science of geometry, at one time the only instrument of culture among the Greeks, and so esteemed by Plato that he is said to have written over his door, "Let no one enter here who does not know geometry," in all its conceptions, propositions, and demonstrations, rests upon the conception of that which has no parts, no magnitude. The old saw of the school-men was, "*Ex nihilo nihil fit.*" If each visible solid owes its form to superficies, and each superficies its form to lines, and each line its form to a point—and a point has no form, because it has no parts—then, who shall stone the man that cries out, "*Ex nihilo geometria fit?*"

But lay the first three definitions of geometry side by side: 1. "A point is that which has no parts, or which has no magnitude." 2. "A line is length without breadth." 3. "The extremities of a line are points." Study these, and you will probably get the following results: That which has no parts produces all the parts of that which occupies space without occupying space, and which, although it occupies no space, has extremities, to the existence of which it owes its own existence; and those extremities determine the existence of that which has parts made up of multiplications of its extremities which have no parts. Now, you must know at least that much, or else stay out of Plato's house.

This useful science, without which men could not measure their little plantations, or construct their little roads on earth, much less traverse and triangulate the ample fields of the skies, lays for its necessary foundation thirty-five definitions, three postulates, and twelve axioms, the last being propositions which no man has ever proved; and these fifty sentences contain as much that is incomprehensible, as much that must be granted without being proved, as much that must be believed, although it cannot be proved, as can be found in all the theological and religious writings from those of John Scotus Erigina down to those of Richard Watson, of England, or Charles Hodge, of Princeton.

Does any man charge that this is a mere logical juggle? Then he shall be called upon to point out wherein it differs from the methods of those who strive to show that there is a real conflict between real

science and real religion. If any man shall charge me with being an infidel as touching geometry, and try to turn me out of the church of science, I shall become hotly indignant, because I know that Euclid did not believe more in geometry than I do, and I believe as much in the teachings of geometry as I do in the teachings of theology, regarding them both, as Aristotle did, as mere human sciences, ranking theology with psychology, geology, and botany. And, being by profession a theologian, I certainly believe in theology.

And this brings us back to what was stated in the beginning, as one of the causes of this cry of "conflict." It is the confounding of theology with religion. Theology is not religion any more than psychology is human life, or zoölogy is animal life, or botany is vegetable life. Theology is objective; religion is subjective. Theology is the scientific classification of what is known of God; religion is a loving obedience to God's commandments. Every religious man must have some theology, but it does not follow that every theologian must have some religion. We never knew a religious man without some kind of a theology, nor can we conceive such a case. But we do know some theologians who have little religion, and some that seem to have none. There may be a conflict between theology and some other sciences, and religious men may deplore *that* conflict, or may not, according to their measure of faith. There are those whose faith is so large and strong that they do not deplore such a conflict, because they know that if, for instance, a conflict should come between geology and theology, and geology should be beaten, it will be so much the better for religion; and if geology should beat theology, still so much the better for religion: according to the spirit of the old Arabic adage, *If the pitcher fall on the stone, so much the worse for the pitcher; and if the stone fall on the pitcher so much the worse for the pitcher.* Geologists, psychologists, and theologists, must all ultimately promote the cause of religion, because they must confirm one another's truths, and explode one another's errors; and a religious man is a man whose soul longs for the truth, who loves truth because he loves God, who knows if the soul be sanctified it must be sanctified by the truth, even as the mind must be enlarged and strengthened by the truth. He knows and feels that it would be as irreligious in him to reject any truth found in Nature, as it would be for another to reject any truth found in the Bible.

But there is no necessary conflict between even theology and any other science. Theology has to deal with problems into which the element of the infinite enters. It will therefore have concepts some two of which will be irreconcilable, but not therefore contradictory. For instance, to say that God is "an infinite person" is to state the agreement of two concepts which the human mind is supposed never to have reconciled, and never to be able to reconcile. But they are

not contradictory. If one should say that there is in the universe a circular triangle, we should deny it, not because the concept of a triangle is *irreconcilable* with the concept of a circle, as consistent in the same figure, which is quite true, but because they are *contradictory*. What is irreconcilable to you may be reconcilable to another mind, because "irreconcilable" indicates the relation of the concept to the individual intellect; but what is contradictory to the feeblest is contradictory to the mightiest mind, because "contradictory" represents the relation of the concepts to one another.

In the definition of a *person* there is nothing to exclude infinity, and in the definition of *infinite* there is nothing to exclude personality. There is no more exclusion between "person" and "infinite" than between "line" and "infinite;" and yet we talk of infinite lines, knowing the irreconcilability of the ideas, but never regarding them as contradictory.

Writers of great ability sometimes fall into this indiscrimination. For instance, a writer whom I greatly admire, Dr. Hill, former President of Harvard College, in one paragraph (on "The Uses of Mathesis," in *Bibliotheca Sacra*), seems twice to employ "contradictory" in an illogical sense, even when he is presenting an illustration which goes to show most clearly that in other sciences, as well as in theology, there are propositions which we cannot refuse to accept, because they are not contradictory, although they are irreconcilable; in other words, that there are irreconcilable concepts which are not contradictory, for we always reject one or the other of two contradictory concepts or propositions.

That is so striking an illustration of the mystery of the infinite that I will reproduce it. On a plane imagine a fixed line, pointing north and south. Intersect this at an angle of ninety degrees by another line, pointing east and west. Let this latter rotate at the point of intersection, and at the beginning be a foot long. At each approach of the rotating line toward the stationary line let the former double its length. Let each approach be made by bisecting the angle. At the first movement the angle would be forty-five degrees, and the line two feet in length; at the second, the angle twenty-two and one-half degrees, and the line four feet; at the third, the angle eleven and one-fourth degrees, and the line eight feet; at the fourth, the angle five and five-eighths degrees, and the line sixteen feet; at the fifth, the angle two and thirteen-sixteenths degrees, and the line thirty-two feet, and so on. Now, as this bisecting of the angle can go on indefinitely before the rotating line can touch the stationary line at all its points, it follows that before such contact the rotating line will have a length which cannot be stated in figures, and which defies all human computation. It can be mathematically demonstrated that a line so rotating, and increasing its length in the inverse ratio of its angle with the meridian, will have its end always receding from the meridian and ap-

proaching a line parallel to the meridian at a distance of 1.5708. We can show that the rotating line can cross the stationary line by making it do so as on a watch-dial, and yet we can demonstrate that if it be extended indefinitely it can never touch the stationary line, nor come at the end even as near as eighteen inches to it.

Here are two of the simplest human conceptions, between which we know that there is no contradiction, rendered absolutely irreconcilable to the human intellect by the introduction of the infinite. There is no religion here. And yet there is no mystery in either theology or religion more mysterious than the mystery of the infinite, which we may encounter whenever we attempt to set our watches to the right time if they have run more than an hour wrong.

Another error has been the occasion of this cry of "conflict." It is the confounding of "the Church" with "religion." This confusion has led many an honest soul astray, and is the fallacy wherewith shrewd sophists have been able to overthrow the faith of the ignorant. If the Church—and, in all my treatment of this topic, I must be understood as using "the Church," not as signifying "the holy Church universal," but simply in the sense in which antagonistic scientists employ it—if *the Church* and *religion* be the same, the whole argument must be given up, and it must be admitted that there is a conflict between religion and science, and that religion is in the wrong. Churchmen are guilty of helping to strengthen, if indeed they are not responsible for creating, this error. It has at length been presented plumply to the world in the book of Prof. J. W. Draper, entitled a "History of the Conflict between Religion and Science." The title assumes that there is such a conflict. See how it will read with synonyms substituted: "History of the Conflict between *Loving Obedience to God's Word* and *Intelligent Study of God's Works.*" Does Dr. Draper believe there is such a conflict? It is not to be supposed that he does. How, then, did he come to give his book such a title? From a confusion of terms, as will be observed by the perusal of three successive sentences in his preface: "The *papacy* represents the ideas and aspirations of two-thirds of the population of Europe. It insists on a political supremacy, ... loudly declaring that it will accept no reconciliation with modern civilization. The antagonism we *thus* witness between *religion* and science," etc. Now, if "the papacy" and "religion" be synonymous terms, representing equivalent ideas, Dr. Draper's book shows that all good men should do what they can to extirpate religion from the world; but if they are not—and they are not—then the book is founded on a most hurtful fallacy, and must be widely mischievous. Their share of the responsibility for the harm done must fall to churchmen.

No, these are not synonymous terms. "The Church" is *not* religion, and religion is *not* "the Church." There may be a church and no religion; there may be religion and no church, as there may be an

aqueduct without water, and there be water without an aqueduct. God makes water, and men make aqueducts. Water was before aqueducts, and religion before churches. God makes religion, and men make churches. There are irreligious men in every church, and there are very religious men in no church. Any visible, organized church is a mere human institution. It is useful for the purpose of propagating religion so long as it confines itself to that function and abstains from all other things. The moment it transcends that limit, it is an injurious institution. In either case it is merely human, and we wrong both religion and the Church when we claim for the latter that it is not a human institution. The Church of England is as much a human institution as the Royal Society; and the same may be said of the Church of Rome and the Royal Florentine Academy. A church is as much an authority in matters of religion as a society is in matters of science, and no more. "The Church" has often been opposed to science, and so it has to religion; but "the society" has often been opposed to religion, and so it has to science. "The Church," both before and since the days of Christ, has stood in opposition to the Bible, the text-book of Jewish and Christian religionists, quite as often as it has to science. But "the society," or "the academy," has stood in opposition to science quite as often as it has to religion. Sometimes the sin of one has been laid upon the other, and sometimes the property of one has been scheduled as the assets of the other. It is time to protest, in the interests of the truth of God, and in the name of the God of truth, that religion no longer be saddled with all the faults of the churchmen, all the follies of the scientists, and all the crimes of the politicians. It was not religion which brought Galileo to his humiliating retraction, about which we hear so much declamation; it was "the Church."

But why should writers of the history of science so frequently conceal the fact that "the Church" was instigated thereunto not by religious people, but scientific men—by Galileo's *collaborateurs?* It was the jealousy of the scientists which made use of the bigotry of the churchmen to degrade a rival in science. They began their attacks not on the ground that religion was in danger, but on such scientific grounds as these, stated by a professor in the University of Padua—namely, that as there were only seven metals, and seven days in the week, and seven apertures in man's head, there could be only seven planets! And that was some time before these gentlemen of science had instigated the sarcastic Dominican monk to attempt to preach Galileo down under the text, *Viri Galilæi, quid statis adspicientes in cœlum?*

In like manner, politicians have used "the Church" to overthrow their rivals. "The Church" is the engine which has been turned against freedom, against science, against religion. It would be as logical and as fair to lay all "the Church's" outrages against human

rights and intellectual advancement at the door of religion as it would be to lay all its outrages against religion at the door of science and government, because "the Church" has seldom slaughtered a holy martyr to the truth without employing some forms of both law and logic.

Science exists for the sake of religion, and because of religion. If there had been no love for God in the human race, there had been no study of the physical universe. The visible cosmos is God's love-letter to man, and religion seems to probe every corner of the sheet on which such love is written, to examine every phrase, and study every connection. A few upstarts of the present day, not the real men and masters of science, ignore the fact that almost every man who has made any great original contribution to science, since the revival of letters, was a very religious man; but their weak wickedness must not be charged to science any more than the wicked weakness of ecclesiastics to religion.

Copernicus, who revolutionized astronomy, was one of the purest Christians who ever lived—a simple, laborious minister of religion, walking beneficently among the poor by day, and living among the stars by night; and yet one writer of our day has dared to say, in what he takes to be the interest of science, that Copernicus was "aware that his doctrines were totally opposed to revealed truth." Was anything worse ever perpetrated by theologian, or even ecclesiastic? Could *any* man believe in any doctrine which he *knew* was opposed to any truth, especially if he believed that God had revealed that truth? It were impossible, especially with a man having the splendid intellect and the pure heart of Copernicus, who died believing in his "*De Orbium Cœlestium Revolutionibus*," and also in the Bible. And this is the inscription which that humble Christian ordered for his tomb: "*Non parem Paulo veniam requiro, gratiam Petri neque posco; sed quam in crucis ligno dederis latroni, sedulus oro.*"

Tycho Brahe, who, although he did not produce a system which won acceptance, did, nevertheless, lay the foundation for practical astronomy, and build the stairs on which Kepler mounted to his grand discoveries, was a most religious man. He introduces into one of his scientific works ("*Astronomiæ Instauratio Mechanica*," p. A) this sentence: "No man can be made happy, and enjoy immortal life, but through the merits of Christ, the Redeemer, the Son of God, and by the study of his doctrines, and imitation of his example."

John Kepler was a man in whose life the only conflict between science and religion seemed to be as to which should yield the most assistance to the other. He wrought as under Luther's motto, "*Orasse est studisse.*" He prayed before he worked, and shouted afterward. The more he bowed his soul in prayer, the higher his intellect rose in its discoveries; and, as those discoveries thickened on

his head, it bowed in humbler adoration. And so that single man was able to do more for science than all the irreligious scientists of the last three centuries have accomplished, while he bore an appalling load of suffering with a patience that was sublime, and, dying, left this epitaph for his tombstone: "*In Christo pie obiit.*"

Of Sir Isaac Newton's, and Michael Faraday's, and Sir William Hamilton's, and Sir James Y. Simpson's religious life, not to mention the whole cloud of witnesses, we need not tell what is known to all men. But the history of science shows that not the most gifted, not the most learned, not the most industrious, gain the loftiest vision, but that only the pure in heart see God. And all true science is a new sight of God.

Herbert Spencer says: "Science may be called an extension of the perceptions by means of reasoning" ("Recent Discussions," p. 60). And we may add, religion may be called an extension of the perceptions by means of faith. And having so said, have we not paraphrased Paul? "Faith is confidence in things hoped for, conviction of things not seen" (Heb. xi. 1). Science has the finite for its domain, religion the infinite; science deals with the things seen, and religion with the things not seen. When Dr. Hutton, of Edinburgh, announced, in the last century, "In the economy of the world I can find no traces of a beginning, no prospect of an end," it is said that scientific men were startled and religious men were shocked. Why should they be? The creation of the universe and its end are not questions of science, and can be known only as revealed to faith. And so Paul says: "Through faith we apprehend intellectually that the worlds have been framed by the word of God, so that that which is seen may have sprung from that which is not seen" (Heb. xi. 3).

PLASTICITY OF INSTINCT.

By GEORGE J. ROMANES.

NOW that the doctrine which is maintained by Mr. Douglass A. Spalding on this subject has proved itself so completely victorious in overcoming the counter-doctrine of "the individual-experience psychology"—and this along the whole line both of fact and theory—it seems unnecessary for any one to adduce additional facts in confirmation of the views which Mr. Spalding advocates.[1] I shall therefore confine myself to detailing a few results yielded by experiments which were designed to illustrate the subordinate doctrine thus alluded to in Mr. Spalding's article:

[1] *See* POPULAR SCIENCE MONTHLY for January, 1876.

"Though the instincts of animals appear and disappear in such seasonable correspondence with their own wants and the wants of their offspring as to be a standing subject of wonder, they have by no means the fixed and unalterable character by which some would distinguish them from the higher faculties of the human race. They vary in the individuals as does their physical structure. Animals can learn what they did not know by instinct, and forget the instinctive knowledge which they never learned, while their instincts will often accommodate themselves to considerable changes in the order of external events. Everybody knows it to be a common practice to hatch duck's-eggs under a common hen, though in such cases the hen has to sit a week longer than on her own eggs. I tried an experiment to ascertain how far the time of sitting could be interfered with in the opposite direction. Two hens became broody on the same day, and I set them on dummies. On the third day I put two chicks a day old to one of the hens. She pecked at them once or twice, seemed rather fidgety, then took to them, called them to her, and entered on all the cares of a mother. The other hen was similarly tried, but with a very different result. She pecked at the chickens viciously, and both that day and the next stubbornly refused to have anything to do with them," etc.

It would have been well if Mr. Spalding had stated whether these two hens belonged to the same breed; for, as is of course well known, different breeds exhibit great variations in the character of the incubatory instinct. Here, for instance, is a curious case: Spanish hens, as is notorious, scarcely ever sit at all; but I have one purely-bred one, just now, that sat on dummies for three days, after which time her patience became exhausted. However, she seemed to think that the self-sacrifice she had undergone during these three days merited some reward, for, on leaving the nest, she turned foster-mother to all the Spanish chickens in the yard. These were sixteen in number, and of all ages, from that at which their own mothers had just left them up to full-grown chickens. It is remarkable, too, that although there were Brahma and Hamburg chickens in the same yard, the Spanish hen only adopted those that were of her own breed. It is now four weeks since this adoption took place, but the mother as yet shows no signs of wishing to cast of her heterogeneous brood, notwithstanding some of her adopted chickens have grown nearly as large as herself.

The following, however, is a better example of what may be called plasticity of instinct: Three years ago I gave a pea-fowl's egg to a Brahma hen to hatch. The hen was an old one, and had previously reared many broods of ordinary chickens with unusual success even for one of her breed. In order to hatch the pea-chick she had to sit one week longer than is requisite to hatch an ordinary chick, but in this there is nothing very unusual, for, as Mr. Spalding observes, the same thing happens with every hen that hatches out a brood of duck-

lings.[1] The object with which I made this experiment, however, was that of ascertaining whether the period of maternal care subsequent to incubation admits, under peculiar conditions, of being prolonged; for a pea-chick requires such care for a very much longer time than does an ordinary chick. As the separation between a hen and her chickens always appears to be due to the former driving away the latter when they are old enough to shift for themselves, I scarcely expected the hen in this case to prolong her period of maternal care, and indeed only tried the experiment because I thought that if she did so the fact would be the best one imaginable to show in what a high degree hereditary instinct may be modified by peculiar individual experiences. The result was very surprising. For the enormous period of eighteen months this old Brahma hen remained with her ever-growing chicken, and throughout the whole of that time she continued to pay it unremitting attention. She never laid any eggs during this lengthened period of maternal supervision, and, if at any time she became accidentally separated from her charge, the distress of both mother and chicken was very great. Eventually the separation seemed to take place on the side of the peacock; but it is remarkable that, although the mother and chicken eventually separated, they never afterward forgot each other, as usually appears to be the case with hens and their chickens. So long as they remained together the abnormal degree of pride which the mother showed in her wonderful chicken was most ludicrous; but I have no space to enter into details. It may be stated, however, that both before and after the separation the mother was in the habit of frequently combing out the top-knot of her son—she standing on a seat, or other eminence of suitable height, and he bending his head forward with evident satisfaction. This fact is particularly noteworthy, because the practice of combing out the top-knot of their chickens is customary among pea-hens. In conclusion, I may observe, that the peacock reared by this Brahma hen turned out a finer bird in every way than did any of his brothers of the same brood which were reared by their own mother, but that, on repeating the experiment next year with another Brahma hen and several pea-chickens, the result was different, for the hen deserted her family at the time when it is natural for ordinary hens to do so, and in consequence all the pea-chickens miserably perished.

I have just concluded another experiment which is well worth recording: A bitch ferret strangled herself by trying to squeeze through too narrow an opening. She left a very young family of three orphans. These I gave, in the middle of the day, to a Brahma hen which had been sitting on dummies for about a month. She took to them almost immediately, and remained with them for rather more

[1] The greatest prolongation of the incubatory period I have ever known to occur was in the case of a pea-hen which sat very steadily on addled eggs for a period of four months, and had then to be forced off in order to save her life.

than a fortnight, at the end of which time I had to cause a separation, in consequence of the hen having suffocated one of the ferrets by standing on its neck. *During the whole of the time that the ferrets were left with the hen the latter had to sit upon the nest;* for the young ferrets, of course, were not able to follow the hen about as chickens would have done. The hen, as might be expected, was very much puzzled at the lethargy of her offspring. Two or three times a day she used to fly off the nest, calling upon her brood to follow; but, upon hearing their cries of distress from cold, she always returned immediately and sat with patience for six or seven hours more. I should have said that it only took the hen one day to learn the meaning of these cries of distress; for after the first day she would always run in an agitated manner to any place where I concealed the ferrets, provided that this place was not too far away from the nest to prevent her from hearing the cries of distress. Yet I do not think it would be possible to conceive of a greater contrast than that between the shrill peeping note of a young chicken and the hoarse growling noise of a young ferret. On the other hand, I cannot say that the young ferrets ever seemed to learn the meanings of the hen's clucking. During the whole of the time that the hen was allowed to sit upon the ferrets she used to comb out their hair with her bill, in the same way as hens in general comb out the feathers of their chickens. While engaged in this process, however, she used frequently to stop and look with one eye at the wriggling nest-full with an inquiring gaze expressive of astonishment. At other times, also, her family gave her good reason to be surprised; for she used often to fly off the nest suddenly with a loud scream—an action which was doubtless due to the unaccustomed sensation of being nipped by the young ferrets in their search for the teats. It is further worth while to remark that the hen showed so much uneasiness of mind when the ferrets were taken from her to be fed, that at one time I thought she was going to desert them altogether. After this, therefore, the ferrets were always fed in the nest, and with this arrangement the hen was perfectly satisfied—apparently because she thought that she then had some share in the feeding process. At any rate she used to cluck when she saw the milk coming, and surveyed the feeding with evident satisfaction.

Altogether I consider this a very remarkable instance of the plasticity of instinct. The hen, it should be said, was a young one, and had never reared a brood of chickens. A few months before she reared the young ferrets she had been attacked and nearly killed by an old ferret which had escaped from his hutch. The young ferrets were taken from her several days before their eyes were open.

In conclusion I may add that, a few weeks before trying this experiment with the hen, I tried a similar one with a rabbit. In this case the ferret was newly born, and I gave it to a white doe-rabbit which had littered six days before. Unlike the hen, however, she per-

ceived the imposture at once, and attacked the young ferret so savagely that she broke two of its legs before I could remove it. To have made this experiment parallel with the other, however, the two mothers ought to have littered on the same day. In this case the result would probably have been different; for I have heard that under such circumstances even such an intelligent animal as a bitch may be deceived into rearing a cat, and *vice versa.—Nature.*

FLYING-MACHINES AND PÉNAUD'S ARTIFICIAL BIRD.[1]

TRANSLATED FROM THE JOURNAL DE PHYSIQUE,

BY ALFRED M. MAYER,

PROFESSOR IN THE STEVENS INSTITUTE OF TECHNOLOGY.

NUMEROUS attempts have been made at different times to construct a machine capable of propelling itself through the air. All kinds of aërial propellers have in turn been tried; such as screws, beating wings, umbrellas which open and shut during their reciprocating motion, inclined planes, aërial wheels. But though many of these projects called forth considerable inventive ability, yet, until quite recently, the *helicopteron* (from ἑλικός, any thing spiral or twisted, and πτερόν, a wing—that is, a machine furnished with an aërial screw-propeller) was the only type of machine which had succeeded in raising itself in flight. Several of these helicopterons have been constructed since 1784, at which date Bienvenu made the first that flew. The best known and the most perfect was that which Ponton d'Amécourt constructed in 1864, and which raised itself for a moment by a sudden motion to a height of two and a half metres. It was formed of two superposed right and left handed screws, put in motion by a watch-spring. All other methods of artificial flight, including those of propellers with wings beating the air like those of a bird, remained ineffective, and were the subjects of conflicting hypotheses as to the nature of flight.

In beginning our studies, we have thought that the best means of getting rid of the multiplicity of hypotheses and of conflicting opinions would be to divide the flying-machines that have been invented into a small number of general types; then to reduce each of these types to its essential elements, and finally to design a flying-machine of each of these simplified types possessing all the really essential parts, and easy to construct.

Leaving out of consideration the inventions which are evidently defective, we have thought it possible to divide the majority

[1] The Academy of Sciences of Paris, at its meeting in June, 1875, awarded to M. Pénaud a prize for the discoveries and inventions described in this article.

of the systems of artificial flight into *helicopterons*, *areoplanes*, and *orthopterons* (from ὀρθός, straight, and πτερόν, a wing). The helicopterons sustain themselves by the aid of screws whose axes of rotation are nearly vertical. They may be made to progress either by these vertical screws or by special screw-propellers. The areoplanes have propelling surfaces which are nearly plane and slightly inclined to the horizon. A horizontal motion is given to these surfaces generally by means of screws. Finally, in the orthopterons, the propelling organs are surfaces moving in vertical directions, and generally having reciprocating motions. In this system are embraced the wings of birds and the moving surfaces of the tails of fishes.

The knowledge of the resistance of the air appeared to us the only guide by which we could arrive at a thorough understanding of the manner in which a machine could sustain itself by the actions of its propelling surfaces on this fluid. We entered upon an attentive study of several imperfectly-understood points appearing to us of capital importance; such as the sustaining screw, the aërial inclined plane, and the theory of the equilibrium of flying-machines. The screw-propeller was well understood from its effects in propelling vessels. These researches, which led us to a small number of very simple general laws, permitted us to determine the manner of action and the proportions of the machines which we desired to construct.

It remained to find a motor the easiest of application. Wood, whalebone, and steel, give forces which are at a minimum when referred to their weight; caoutchouc is much more powerful, but the framework necessary to resist its violent tension is necessarily quite heavy. We then conceived the idea of using the elasticity of the torsion of caoutchouc, which finally led to an easy, simple, and effective method of constructing the models of flying-machines.

We applied the new motor first to the helicopteron, after having previously investigated the curious and valuable actions of caoutchouc when subjected to various successive torsions. In April, 1870, we presented models to M. de la Landelle which rose in flight to more than fifteen metres, hovering and fluttering through large inclined circles, and sustaining themselves during more than twenty seconds.

The great superiority of these results over those obtained with preceding helicopterons encouraged us to apply our motor to other systems of artificial flight. On the 18th of August, 1871, in the presence of the Society of Aërial Navigation, we succeeded in making an areoplane fly with various velocities and in different directions, around one of the circles of the garden of the Tuileries. The success of this machine in its ascending motions and in its perfect equilibrium gave the first successful exhibition of a machine on the areoplane type.

Measured directly, and irrespective of any hypothesis, the force required to sustain and propel the areoplane and the helicopteron proved to be relatively moderate, and did not approach the fabulous

estimations previously given by Navier. This experiment demonstrated that the muscular strength of birds, although notably greater, for equal weights, than that of mammals, did not exceed a reasonable estimation.

Our helicopterons and areoplanes which performed with success on the 2d of July, 1875, before the Physical Society, have a numerous offspring. They have been imitated with various success by Crocé-Spinelli and MM. Montfallet, Pétard, and Tantin.

The action of these machines, in fully confirming our ideas and calculations on the resistance of the atmosphere, encouraged us to attempt the construction of a mechanical bird with flapping wings. The diversity of the hypotheses as to the nature of flight, proposed in France and in England, though bearing witness to the difficulties to be met with in the construction of this mechanism, yet rendered the problem peculiarly interesting.

The experiments heretofore made with mechanical birds had been very discouraging. M. Artingstall and M. Marey had alone obtained effective results. M. Artingstall states that, some thirty years since, he had an artificial bird which flew at the end of a tube jointed on to a steam-boiler. M. Marey, whose beautiful physiological experiments are so well known, constructed, in 1870, artificial insects which, attached to a radial tube carrying a counterpoise equal to two-thirds of their weight, rose and flew in a circle by the aid of their wings. The compressed air which set the wings in motion was conveyed to them through the radial tube from a compression-pump worked by hand.[1] It remained to gain the two-thirds of the weight of the insect and to cause the latter to carry with it its motor instead of having the wings moved by a force conveyed to the insect from without.

Encompassed by the divers hypotheses of the action of the wing given by Borelli, Huber, Dutrochet, Strauss-Durckeim, Liais, Pettigrew, Marey, d'Esterno, De Lucy, Artingstall, etc., and in view of the very complicated motions they had assigned to that organ and to each of its quills—motions which are, for the most part, inimitable in a mechanical bird—we decided to reason out for ourselves, by relying on the laws of the resistance of the air and on some of the most simple facts of observation, what are *the motions of the wing really necessary to flight*. We found—1. *A double oscillation*, a depression, and an elevation of the wings transverse to the path of flight. 2. The change of the plane of the same during this double motion; the lower surface of the wing facing below and behind during its depression, so as to sustain the bird, the same surface of the wing facing below and in front during its elevation, so that the wing is raised with the least resistance by cutting the air with its edge while the bird flies. These movements, moreover, were admitted to be correct by a large num-

[1] *See* Fig. 87, on page 202 of Marey's "Animal Mechanism," published in the "International Scientific Series."

ber of observers, and have been concisely demonstrated by Strauss-Durckeim, Liais, and Marey.

But, in considering the difficulty of the construction of our mechanical bird, we were obliged, notwithstanding our desire to make a machine which should be simple and easy to understand, to try to perfect those actions we have somewhat summarily described. It is evident that the different parts of the wing, from its base to its extremity, act on the air under very different conditions. The interior part of the wing, having small velocity, produces little propelling effect at any moment of its beat; but it is far from being useless, and one may imagine how, by presenting its lower face downward and slightly facing the front, it acts during the rapid translation of the bird, like a kite, as well while the wing is being elevated as during its downward motion, and thus sustaining in a continuous manner a portion of the weight of the bird. The middle portion of the wing has a junction intermediate between that of the interior and that of the outer portion, or end, of the wing; so that the wing, during its action, is twisted on itself in a continuous manner from its base to its extremity. The plane of the wing at its base varies but little during flight; the plane of the median part of the wing is very much displaced on one and the other side of its mean position; finally, the outer part of the wing, and especially its tip, experiences considerable change of plane. This warping of the wing is modified at each instant during its elevation and depression, in the manner just indicated; at the extreme points of its beat the wing is nearly plane. The action of the wing is thus seen to be intermediate between that of an inclined plane and that of a screw with a very long and continually variable pitch.

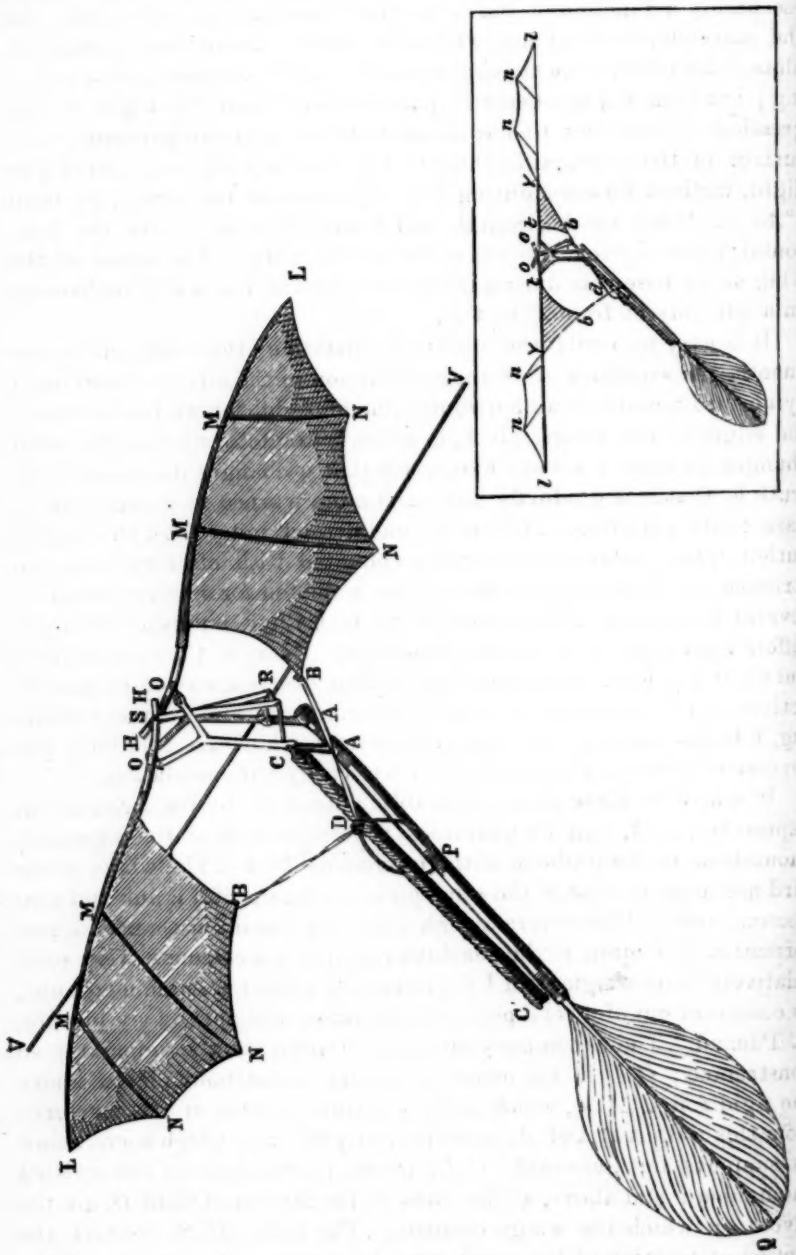
Notwithstanding the differences found to exist in the hypotheses of various authors when compared with one another and with the one just given, still one or the other of these writers confirms the greater portion of the ideas just advanced. Thus the torsion of the wing had already been pointed out by Dutrochet, and especially by Pettigrew, who long maintained this opinion; only he has taken, according to our view, the change of form occurring during the elevation of the wing for that of the form occurring during its depression, and *vice versa*. These authors clearly saw how the articulations of the bones, the ligaments of the wing, the imbrication and elasticity of the quills, bring about the above result. M. d'Esterno had explained the continuous effect, like that of a kite, of the interior portion of the wing during its depression and elevation; and M. Marey had very appropriately designated that portion of the wing as "passive," at the same time, however, maintaining that the most important action of the wing during flight is due to a general change of its plane produced by the rotation of the humerus on itself.

According to our view there is a sharp distinction to be made be-

tween hovering and the ordinary flight of progression, while the amplitude of the changes in the plane of the extremity of the wing is essentially a function of the velocity of translation of the bird. At the extremity of the wing, where the most considerable changes of plane takes place, these changes equal 90°, and even more, during hovering; but then displacements of plane are far less in the flight of progression. According to our calculations the extreme portions of the surface of the terminal feathers of the crow's wing are, during free flight, inclined forward during the depression of the wing only from 7° to 11° below the horizontal, and from 15° to 20° above the horizontal plane during the elevation of the wing. The plane of the wing at its base acts during the above motions like a kite inclined at an angle only of from 2° to 4°.

It is easy to verify the slight inclination of the wing, and consequently the smallness of its angles of action in the air, by observing a flying bird moving in an horizontal line of sight, for we then see only the edges of the wings. It is, in short, inexact to say that the wing changes its *plane;* we can barely say that it changes its *planes.* The truth is, that it is gradually more and more warped in going from its base to its extremity. It was so understood, indeed, by an English author, whose labors we became acquainted with after we had constructed our bird, and to him we are indebted for having saved us several researches. The theory of Sir G. Cayley, published in 1810, differs from ours but in a few particulars. He is of the opinion that the outer portion of the wing in ascending exerts always a propulsive action, and he attributes to the propelling parts and to the sustaining, kite-like parts of the wing, proportions which are relatively the reverse of those to which we have been led by our calculation.

It was with these ideas, favorably judged of by the Academy in September, 1871, that we undertook the application of the torsion of caoutchouc to the problem of the mechanical bird. The wings of our bird are made to beat in the same plane by means of a crank and connecting rods. After several rough trials, we found out that the transformation of motion in the machine required a mechanism very solid relatively to its weight, and I requested M. Tobert, an able mechanist, to construct out of steel a piece of mechanism designed by my brother, E. Pénaud. The accompanying figure represents the apparatus so constructed; *C C'* is the motor of twisted caoutchouc placed above the rigid rod, *P A A*, which is the vertebral column of the machine; from this rod, at *A* and *A*, ascend two rigid forks, which serve below as supports for the crank, *C R*, which is attached to the twisted caoutchouc; and above, at the ends of the forks at *O* and *O*, are the pivots on which the wings oscillate. The links, *R S*, convert the motion of rotation of the crank into the reciprocating motion of the arms, *O M L*, *O M L*. At *Q* is a steering-tail, which we found by experience was best made from one of the long feathers of a peacock's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tail, and which can be inclined upward, or downward, or to one side, and be loaded with wax so that the centre of gravity of the machine can be brought to the proper position.

The warping of the wings, *O L*, is obtained by the mobility of the wing and of the little fingers, *M N*, supporting them on the large rods, *O M L*, which do not partake of this rotation. A little ligament of caoutchouc, *D B*, connects the posterior interior angles of the wings with the middle of the central rod of the machine. This ligament, whose function is similar to that of the posterior paws of the bat, plays the part of an elastic sheet to our wing, so closely resembling the topsail of a schooner. The torsions of the wing are thus automatically regulated, as required, by the combined action of the pressure of the air and of this elastic ligament. The interior third of the surface of the wing acts like a kite during the elevation as well as during the depression of the wing. The external two-thirds, corresponding to the primary and secondary quills of birds, propel and sustain the machine during the downward motions of its wings. The little drawing in the corner shows the wings just about to begin their downward beat. During the elevation of the wing the terminal feathers conform to the sinusoidal track along which they progress in the air; it thus only cuts the atmosphere without acting against it. To start the machine, we simply abandon it to itself in the air.

This machine was exhibited before the Society of Aërial Navigation on the 2d of June, 1872, and flew several times more than seven metres—the length of the public hall—raising itself in a continuous manner, with an accelerated velocity, along a line of flight inclined 15° to 20°. In an open space, the artificial bird flew over twelve to fifteen metres, elevating itself during this flight to about two metres. Another model, exhibited before the same society in October, 1874, flew in an horizontal line, vertically upward, and also ascended obliquely.

On the 27th of last November, at a public exhibition, this model flew from one end to the other of the hall of the Horticultural Society (*see Aëronaute*, February, 1875). On the 2d of July, 1875, it performed with success before the French Physical Society. The velocity of its flight is from five to seven metres per second.

The birds of twisted caoutchouc have been a great success.

M. Hureau de Villeneuve, whose zeal in the study of aërial navigation is well known, and who in his many contributions to the theory of flight since 1868 has discussed the inclination to the horizon of the axes of the scapulo-humeral articulations and their posterior convergence, exhibited, on the 20th of June, 1872, a bird moved by twisted caoutchouc, which, he states, elevated itself vertically to a height of nearly one metre. Continuing his researches with perseverance, he again exhibited his apparatus before the Society of Aërial Navigation on the 13th of January, 1875, after having supplied it with wings

similar to those of my bird, and after having adopted several of the peculiarities which had made my machine successful. He then succeeded in giving sustained flight to his machine, which we have ourselves seen fly horizontally nearly seven metres, after having been started by a slight impulse from the hand. M. Tatin, also, in 1874, made two very curious artificial birds, using twisted caoutchouc as a motor. M. Marey has told us that he saw the first named fly in his garden, last November, from eight to ten metres. We have seen the second, nearly identical with our bird, fly in a still more satisfactory manner.

A MUSEUM EXCHANGE.[1]

By Prof. BURT G. WILDER.

THERE are in this country three institutions more or less available for the distribution of material for Natural History instruction: the Smithsonian Institution at Washington, District of Columbia; the (Agassiz) Museum of Comparative Zoölogy, at Cambridge, Massachusetts; and Prof. Ward's establishment at Rochester, New York.

The first is especially rich in American forms, the collections of government surveys, and the types of Baird's descriptions. There are many duplicates, but these are required for the elucidation of the extent of variation within the species, so that they are available for exchanges in only a limited degree.

The peculiar value of the Cambridge Museum comes from the immense amount of material from all parts of the world, upon which zoölogists are enabled to pursue extended investigations, either at the museum, or, under certain conditions, elsewhere.

Agassiz also desired to prepare collections for educational institutions in Massachusetts, and to provide for teachers an opportunity for summer instruction and for the collection of specimens.

But it is evident that the above-mentioned establishments and arrangements are not yet able to meet a rapidly-growing want of the whole country; namely, the *immediate formation of museums* for the illustration of the courses in natural history which are now generally demanded, in not only the colleges and universities (whether real or so called), but also the normal schools, and even those of lower grade.

Such selected collections need not be either very large or very costly. They should embrace mainly *typical* forms, but contain also some of the peculiar or aberrant species of each large group.

It would be well if some one would make out a list of what are desirable in larger or smaller collections. Meantime, the information

[1] Presented at the Detroit meeting of the American Association for the Advancement of Science.

and the material are, to a great extent, obtainable from the catalogues and the museum of Prof. Ward.

A recent examination of this establishment has suggested a brief sketch of its nature, its capacity for supplying the want above indicated, and of the additions which might advantageously be introduced.

Prof. Ward was a pupil of Agassiz, and afterward Professor of Natural History in Rochester University, where he formed a very extensive and well-arranged museum of geology, mineralogy, paleontology, and zoölogy. Desiring to include with this fac-similes of unique fossils in other museums, Prof. Ward spent three years in Europe, and gradually accumulated moulds of famous fossils. The great expense of this undertaking (nearly $20,000) determined him to make duplicates of the casts, and thus, by degrees, originated the now well-known "Ward Series of Casts of Fossils;" and at present, in many of our educational institutions, large and small, the megatherium, iguanodon, ichthyosaurus, and pterodactyl have become as familiar forms as the professors themselves.

The usefulness of this branch of the establishment is now generally recognized, and, with the mineralogical department, has been graphically described by others,[1] so we may pass to the consideration of what has been and may be accomplished by Prof. Ward for the furnishing of zoölogical museums.

At present, mounted insects and stuffed birds receive but little of his attention, but the collections embrace representatives of the leading groups of the whole animal kingdom, more than 13,000 species being represented. The echinoderms and crustacea, being easily preserved in a dry state, are very numerous. They have recently been carefully rearranged and determined by a professional naturalist.

Prof. Ward keeps twenty-two advertisements in foreign journals, and has correspondents in all parts of the globe, near and remote, so that scarcely a week passes without his receiving word of the sending to him of rare forms.

At the time of our visit he was receiving the results of a late trip to Europe (where he had expended about $10,000 for specimens). On the same day arrived the skins and skeletons of two camels, the one from Asia Minor, the other from Turkey. The taxidermists were engaged upon a grizzly bear, a 1,000-pound turtle, and the now-famous donkey which slew a lion in Cincinnati; while the osteologists were mounting a whale's skeleton for the Peabody Academy of Science at Salem, Massachusetts, and would then commence upon a large series of skeletons for the Smithsonian Institution.

A specimen of the rare tiger-shark (*Crossorhinus dasypogon*) had just arrived from Australia.

Ten men are constantly employed in the reception and arrange-

[1] As by Prof. E. S. Morse, in the *American Naturalist* for April, 1873, and Prof. Alexander Winchell, in the *College Courant* for October 1, 1870.

ment of these specimens, in the preparation of skins and the mounting of skeletons. The chief osteologists and taxidermists were brought from Europe, and their salaries are more than is received by many an assistant professor.

In alcohol are fishes and reptiles, such as the *Lepidosteus*, *Polyodon*, and *Amia*, of our Western rivers, the *Calamoichthys* of Africa, the *Siren* and *Amphiuma* of South Carolina, and the *Proteus* of Europe; while in dry, upper rooms hang hundreds of skins of quadrupeds, large and small, from all parts of the world, and carefully labeled.

The excellence and trustworthiness of the work done by Prof. Ward are further attested by the extent to which he is employed by the Smithsonian Institution, the Cambridge Museum, and others both here and abroad. Indeed, it is no unusual thing for material to come from Europe to Rochester, and be returned to some Continental museum.

But, while gladly commending what is done, we would offer a suggestion as to what might be done with great advantage to our educational institutions and a fair profit to Prof. Ward:

1. Such an establishment should supply the lower vertebrates, the *lamprey* and particularly *amphioxus*, of which, also, sections might be prepared for the microscope.

2. There should be kept, or prepared to order, series of *embryos* of some common animals: among mammals the pig, and among batrachians the frog, are very easily obtained. All *embryos* are, in some respects, more valuable than adults, and, if they were on hand, a demand would surely arise.

3. A series of brains should be added. The models of these, whether plaster or *papier-maché*, are poor substitutes for the real specimens. Nor need the number be very large; a dozen species would fairly illustrate the modifications of the vertebrate encephalon.

Speaking of brains, we cannot forbear expressing the hope that Prof. Ward may shortly be able to impress his clients with the truth of Prof. Wyman's saying that "a skull is doubled in value by cutting in two." The inside is quite as important as the outside, while such vertical bisection, if carefully made, enables us to secure the two halves of the brain but little injured.[1]

4. Other anatomical preparations of soft parts, sections and dissections, are really desired for instruction, and a few typical preparations could readily be made.

5. Finally, we would suggest to Prof. Ward the expediency of

[1] A case in point occurs while correcting the proof of this article. Prof. Ward has received a "blackfish" (*Elobiocephalus melas*). Knowing that the Cornell University would like the brain, he sends me word; but, as the section of the skull for extraction of the brain would impair its value for most purchasers, we have to take the whole skeleton also. The brain, by-the-way, weighs nearly five pounds, two pounds more than the average human brain, and nearly a pound more than that of Cuvier.

making his establishment a medium of exchange between parties in different localities. For instance, A lives in Central New York; he has plenty of *Menobranchus*, and would exchange them for *Menopoma* from the Ohio River, or the gars and spoonbills of the Mississippi, of which B has more than he wants; while both these parties desire sharks, and skates, and pipe-fishes, and the large lamprey from the seacoast where C lives. To purchase and keep all these and many more such on hand involves an enormous expense and risk to a single individual; whereas, if, under certain conditions, Prof. Ward received good specimens of these forms, and stored them at the owner's risk as to fire, and expense as to alcohol, etc., then he could, at a fair commission, transfer them to those who desired them without the expenditure now incurred.

The arrangement could be made like that of the naturalists' agency for books in Salem, Massachusetts, and a periodical list of specimens and prices could be issued. The prices would serve as guides for either exchange or direct purchase.

Such a system of transfer would, it seems to us, not only enable new institutions to rapidly form type collections for class-room instruction, but also encourage them to collect large numbers of duplicates of the forms peculiar to their localities. In this way we should ascertain the extent of individual variation, the manner and rate of development and growth, and, by preparations made on the spot, the structure of the brains and other soft parts, which are seldom perfectly preserved in specimens sent in alcohol from a distance.

ARE THE ELEMENTS ELEMENTARY?

By F. W. CLARKE,

PROFESSOR OF CHEMISTRY AND PHYSICS IN THE UNIVERSITY OF CINCINNATI.

WHAT are the so-called chemical elements? Are they really elements, or only compounds of remarkable stability? It would be hard to find in physical science a question which has been oftener asked than this. It has furnished all sorts of investigators with abundant food for speculation. Men of the highest scientific ability have grappled with the problem, and left it still unsolved; others have constructed elaborate theories, which claimed to settle everything. Still the debate goes on. We cannot prove that the elements are truly what we call them, nor can we show beyond all doubt that they are compound in their nature. We may, however, weigh the opposing probabilities, and see which side of the question is the stronger. Whichever way the balance turns, the superstructure of chemistry will be but little affected. We know that all our recog-

nized compounds are formed by the union together of two or more supposed elements; and no revelations concerning the nature of the latter can well disturb that established knowledge. However we may speculate, the experimentally-ascertained facts will remain unaltered. They may receive slightly different theoretical interpretations, without having their practical bearings changed in the least degree.

The prevalent view of the subject, that the elements are elementary, is held by philosophical chemists in a purely provisional way. We need a convenient working hypothesis, and these sixty-three substances are elements for aught we absolutely know to the contrary. As far as we are at present experimentally concerned, then, we call them elements, bearing always in mind the possibility that they may be compounds. They have never been decomposed; we have no means adequate to their analysis; not one of them can be obtained from materials in which it does not already exist. But all this evidence is only negative. How do we know but that some future discovery may render possible the decomposition of these supposed elements? Shall we assert positively that we have reached the ultimate analysis, and may never hope to go any farther? Obviously, so definite a statement would be unjustifiable, and no sane chemist would venture to make it. The uncertainty of the subject may well be illustrated by a reference to chemical history. At the beginning of the present century the alkalies and alkaline earths were thought to be elements. They were not decomposable by any means then known, so that the supposition was perfectly fair. A very few years passed away, the galvanic battery was brought into use, and presently it was found that each of these bodies was a compound, containing a metal united with oxygen. Perhaps a similar advance in our knowledge may demonstrate the possibility of decomposing many of the substances now regarded as elementary. Such a discovery might work in either one of three ways. It might largely increase the number of supposed elements, by dividing each one into two or more new bodies. It might reduce the number by proving that our elements were formed by the union, in various proportions, of only a very few simpler substances. Or it might demonstrate the unity of matter, just as recent science has demonstrated the unity of force, and give us only one true element underlying all material forms. Such a culmination of our knowledge would be grand, indeed!

The evidence, then, upon which we assert the elementary nature of the fifty metals and thirteen non-metals, is very incomplete. On this side of the question there is really no other important testimony, save that just cited. Arguing from our present inability to decompose certain bodies, we assume for convenience that they are indecomposable. Now let us see what there is in favor of the opposite view.

One of the first things learned by the student in chemistry is, that the so-called elements are readily classifiable into a few natural groups.

The members of any one of these groups resemble each other chemically in the closest manner, forming compounds of strong similarity, and often are very much alike in their physical properties also. The thought at once arises, Can these elements be totally distinct from each other—have they nothing in common—are these resemblances only due to chance? Such a supposition could scarcely be admitted, since Science excludes chance from her list of natural agencies. These relationships must mean something—but what?

If we look beyond the points of similarity to the points of difference between related elements, we shall find that these too are subject to regularity. The members of a group vary from each other, not in a meaningless, helter-skelter way, but systematically, so that they may be arranged in regular series. Take, for example, the group formed by the strikingly similar metals, calcium, strontium, and barium. If, now, we compare these with reference to any physical property, we shall find that strontium will always be between the other two. It is heavier than calcium and lighter than barium; and the same thing holds true of strontium compounds when compared with the corresponding compounds of its two associates. The integrity of the series is perfect; for in no case can the middle member be placed either at the beginning or the end. The nitrogen group is even more remarkable. Arranging its recognized members in the order of their atomic weight, they are as follows: nitrogen, phosphorus, arsenic, antimony, and bismuth. The first of these elements is gaseous at all known temperatures; phosphorus is a solid, but easily convertible into a gas by heat; arsenic is a denser body still, and less readily vaporized; antimony follows in regular order; and finally, bismuth, the heaviest of the series, can be distilled only with considerable difficulty. Here, then, is a gradation both in specific gravity and in boiling-point, the lowest member of the group, in each of these particulars, being that with the lowest atomic weight; and the reverse. If we ascend from these elements to their compounds, we shall also notice some curious chemical regularities. Each member of the group unites with oxygen to form a pentoxide, from which an acid may be derived. Compare, now, these five acids: nitric is very strong, and violently corrosive; phosphoric is a little weaker, and acts much less vigorously; arsenic is feebler still; antimonic is extremely weak; and the corresponding bismuth compound is just barely recognizable as being an acid at all. Can these regular gradations be purely accidental and meaningless?

Examples like these might be adduced almost indefinitely. Series after series could be brought forward, all illustrating the same principle. Exceptions occur now and then, but they are so few that for present purposes they may be disregarded. Of course they mean something, but they are neither sufficiently abundant nor important enough to affect our arguments. The regularities are so numerous and so re-

markable as to outweigh many times over all seeming variations. All this evidence is, however, inadequate in one respect: the relations thus far pointed out cannot be simply expressed in figures. Are there, then, any numerical relations connecting the elements? This question may be answered, partly by studying their atomic weights, and partly by an examination of their specific volumes.

The regularities which connect the elementary atomic weights have been examined and discussed by many investigators from widely differing points of view. Some chemists have contented themselves with the naked facts; others have considered the bearing of those facts upon chemical theories; and a third class, with less caution than ignorance, have speculated upon them in the wildest and most reckless manner. Of course a full summary of the whole subject, however interesting it might prove, would be out of place in a condensed argument like this. All we can do here is to glance at a few of the many relations known, and afterward consider them in their connection with our main subject. The general reader who cares to go deeper into the question will do well to consult the original papers of Dumas, Gladstone, J. P. Cooke, Kremers, Mendelejeff, and others.

Of the relations now under consideration, the one most frequently cited is as follows: Many elements are most naturally arranged in threes, of which the middle member has an atomic weight very nearly a mean between the atomic weights of the other two. Thus we have calcium, atomic weight, 40; strontium, 87.5; and barium, 137. Here, if the value of strontium were 88.5, it would be an exact mean. Again, chlorine has the atomic weight 35.5; bromine, 80; and iodine, 127; the second being almost precisely midway between the first and third. A still closer agreement with theory is furnished by lithium, sodium, and potassium, whose values are respectively 7, 23, and 39.1. A fourth example is afforded by potassium, 39.1; rubidium, 85.4; and cæsium, 133; while a fifth case is offered by phosphorus, 31; arsenic, 75; and antimony, 122. To be sure, these illustrations afford only an approximation to regularity; but then the variations are themselves somewhat regular. In each of these twos the middle term is just a little too low to be an absolute mean between its associates; that is, the variations from theory are all in one direction. It is hardly possible at present to say whether this means anything, or is only ascribable to accident. One more example of regularity among atomic weights is worth noting, namely, the relation which connects the members of the oxygen group. Here we have oxygen, 16; sulphur, 32; selenium, 79.5; and tellurium, 128. These higher numbers are simple multiples of the lowest; there being only a variation of half a unit (minus) in the case of selenium. Since these elements are very similar in their chemical relations, this regularity is extremely significant. Can it be due to chance, and void of real meaning?

But all these relations *prove* nothing—they merely suggest. Stand-

ing by themselves they would signify comparatively little; but considered with other analogous evidence they help to found an almost overwhelming argument. The concurrent testimony supplied by the specific or atomic volumes of the elements is particularly strong.

The specific volume of any substance is the quotient obtained upon dividing its atomic weight by its specific gravity. This value may be supposed to represent the volume of an atom of the substance plus the sphere of unoccupied space immediately surrounding and belonging to it. Leaving theoretical definitions out of account, however, we shall find, upon comparing the specific volumes of solid and liquid substances, many extraordinary relations. Often, all the members of an elementary group have equal values. This is the case with the closely-related metals platinum, iridium, osmium, palladium, rhodium, and ruthenium. They have different atomic weights and different specific gravities; yet the quotient obtained upon dividing the former by the latter is the same in every instance. The same thing holds good of the group formed by iron, cobalt, nickel, chromium, manganese, copper, and perhaps also uranium. Here the regularity extends even beyond the elements themselves, for their corresponding compounds have, with few exceptions, equal specific volumes also. An altogether different, but on the whole more remarkable, relation is furnished by the alkaline metals lithium, sodium, potassium, and rubidium; whose specific volumes are respectively 11.9, 23.7, 45.1, and 56.2. These values are almost exactly multiples of the first, standing to it in the ratio of 1 : 2 : 4 : 5. The slight variations from accuracy in this case are very far within the limits of experimental error. Almost as remarkable multiple relations are found in several other series, and apply not only to the specific volumes of the solid elements, but to their values in liquid compounds also. Closely connected with this subject is that of crystalline form. As a general, though not invariable rule, elements having equal specific volumes are isomorphous; that is, crystallize alike; a fact which may be extended to a very large number of compound series as well.

It would be easy to go on to almost an indefinite extent multiplying examples of relationship between the elements. There is hardly any set of physical properties which may not be made to emphasize the idea that these substances are internally related. Take, for example, their specific heats, which, multiplied by their atomic weights, give a constant quantity in the neighborhood of 6.3. That is, according to the law of Dulong and Petit, all elementary atoms have equal capacities for heat. But space is limited, so that we must omit the consideration of many important facts, and pass to the theoretical discussion of those already cited. All this evidence suggests quite emphatically that the elements are not totally distinct and independent bodies. Are they, then, compounds formed from a few simple substances, or are they modifications of but one primal matter? Strong

arguments may be adduced in favor of either view, although neither can be yet demonstrated.

The idea that a very few true elements, uniting together in a variety of proportions, may give rise to all the bodies which we now look upon as elementary, derives perhaps its strongest support from an analogy pointed out by Prof. Cooke something like twenty years ago. He first called attention to the many serial relations which connect the members of any elementary group, and then showed how much these groups resemble the homologous series of organic chemistry. In such a series we have a number of compounds each differing from its immediate predecessor in a very definite way. Thus, in the series of alcohol radicles, we have first the hydrocarbon methyl. Adding to this an atom of carbon and two of hydrogen, we get the second member of the series; the third is formed by the same addition to the second, the fourth similarly derived from the third, and so on. The difference between the molecular weights of any two successive members in this series is always the same. Just so in some groups of elements, as we have already seen. The atomic weight of lithium is seven, add sixteen and we get that of sodium, while another increase of sixteen gives the value of potassium. Again, the atomic weight of sulphur is that of oxygen plus sixteen; three times sixteen more brings us to selenium, and another forty-eight reaches the equivalent of tellurium. Here certain multiples of sixteen are missing; do they correspond to the atomic weights of undiscovered elements? Such a speculation is curious, but not very profitable.

The analogy, then, between the groups of elements and the homologous series of organic compounds is quite striking, although it may not be very precise. Hence Cooke suggested that, if the elements were compounds, their resemblances might be explained by supposing them to form series like the hydrocarbons, in which bodies of similar constitution are akin in general properties. Now, this conception was certainly very brilliant, and rendered intelligible many important facts which before it were unclassified. It did not, however, suggest the possible unity of matter, but merely put the ultimate question regarding the nature of the elements a step farther back. Instead of many, it gave us the idea of few elementary bodies; why and how these differed were yet to be found out. Prof. Cooke was, fortunately, too cautious a chemist to put forward views of this sort dogmatically; he did not offer a theory even; he only made suggestions to be taken later at their true value, whatever that might be.

The other side of the question, that of the unity of matter, has been worked up by several chemists in a variety of ways. Some have studied the phenomena of crystallization and drawn their conclusions therefrom; others have taken up the subject from a dynamical point of view. Given atoms of one kind only, how to arrange these in different aggregations so as to present all the phenomena offered by our

supposed elements in their relations to the various modes of energy? Perhaps in the discussion of this problem Gustavus Hinrichs would stand first. His conclusions may be easily questioned, but the ability and ingenuity displayed in reaching them cannot be denied.

To the general reader, or to the beginner in chemistry, the difficulties confronting the unitary view of matter may seem to be very great. Doubtless they are; but then every side of the subject is beset with difficulties. Obstacles must be surmounted, and the worst are not in this direction. The mind unused to speculations of this sort will probably encounter its greatest embarrassment in trying to understand how one substance alone can assume such a diversity of forms. That such a thing is within the limits of possibility, may be illustrated by reference to the facts of allotropy and isomerism. Quite a number of our present elements are known to be capable of existing in a variety of dissimilar modifications. Carbon is found as charcoal, graphite, and diamond; phosphorus exists both in its white and in its red modifications; oxygen is allotropic as ozone. Similar examples are furnished by arsenic, selenium, and, very notably, by sulphur. Among compounds, especially in organic chemistry, many cases occur in which several different bodies have precisely the same elementary composition. For instance, the essential oils of rose, bergamot, orange, lemon, lavender, turpentine, rosemary, nutmegs, myrtle, peppermint, etc., unlike as they may be in outward properties, are all composed of carbon and hydrogen in exactly the same percentages. The same atoms occur, but differently arranged. Many other sets of isomeric bodies are known in which this diversity of atomic arrangement can be distinctly traced, and the reasons for difference clearly pointed out. The limitations of space prevent their description here.

Now, since a single element may exist in several different forms, and since the same atoms can unite together so as to produce compounds very unlike each other, the chief objection to the unitary view is removed. Why may not all the so-called elements be allotropic modifications of one, or else isomeric bodies formed by the union of two or three such modifications? Such a supposition is by no means absurd, although, to be sure, it is not capable of rigid demonstration. It is only a speculation, but then within it are some fair probabilities. These may be strengthened by an appeal to spectroscopic evidence, and to the prevalent hypothesis concerning the origin of our planet.

If we examine the spectra of our supposed elements, we shall notice no more striking fact than the extent to which they differ in complexity. Some bodies give spectra of only one or two lines, while others are represented by hundreds. This atom emits light of a single wave-length, that one gives out rays of nearly half a thousand different kinds. Now, what do these facts mean? Do they indicate structural differences within molecules such that each bright line in a spectrum corresponds to a true element? Such a notion, if true,

would lead to an alarming multiplication of elementary bodies, increasing our present confusion to an indefinite extent. If every possible wave-length of light represented a special element, the number of elements would be infinite. Clearly, then, this speculation, although frequently suggested, has very little to recommend it, and need not be entertained. Still, the fact of varying complexity among the elementary spectra remains to be accounted for. It certainly suggests a corresponding difference of complexity among the elements themselves, but of what nature? This question can hardly be answered directly, although it admits of interesting discussion, for which, unfortunately, we have little space to spare. Suffice it to say that spectroscopic phenomena are quite in harmony with the idea that all matter is at bottom one, our supposed atoms being really various aggregations of the same fundamental unit. It is approximately true that the simpler spectra are furnished by the elements of low atomic weight, while the multitudes of lines come from the heavier atoms. There are prominent exceptions to this rule, still it affords some support to our central idea.

But the spectroscope makes its most emphatic suggestions in favor of the unity of matter when it is applied to the study of the heavenly bodies. This subject I discussed in THE POPULAR SCIENCE MONTHLY for January, 1873, and some months later Lockyer gave it prominence in England, his paper calling forth a good deal of comment. Therefore, only a brief *résumé* of my original suggestions is desirable now.

Everybody knows that the nebular hypothesis, as it is to-day, draws its strongest support from spectroscopic facts. There shine the nebulæ in the heavens, and the spectroscope tells us what they really are, namely, vast clouds of incandescent gas, mainly, if not entirely, hydrogen and nitrogen. If we attempt to trace the chain of evolution through which our planet is supposed to have grown, we shall find the sky is full of intermediate forms. The nebulæ themselves appear to be in various stages of development; the fixed stars or suns differ widely in chemical constitution and in temperature; our earth is most complex of all. There are no "missing links" such as the zoölogist longs to discover when he tries to explain the origin of species. First, we have a nebula containing little more than hydrogen; then a very hot star with calcium, magnesium, and one or two other metals added; next comes a cooler sun in which free hydrogen is missing, but whose chemical complexity is much increased; at last we reach the true planets with their multitudes of material forms. Could there well be a more straightforward story? Could the unity of creation receive a much more ringing emphasis? We see the evolution of planets from nebulæ still going on, and parallel with it an evolution of higher from lower kinds of matter.

Just here, perhaps, is the key to the whole subject. If the elements are all in essence one, how could their many forms originate

save by a process of evolution upward? How could their numerous relations with each other, and their regular serial arrangements into groups, be better explained? In this, as in other problems, the hypothesis of evolution is the simplest, most natural, and best in accordance with facts. Toward it all the lines of argument presented in this article converge. Atomic weights, specific volumes, and spectra, all unite in telling the same story, that our many elements have been derived from simpler stock.

I know that all this is only speculation, but surely it is not baseless. Science is constantly reaching forward from the known to the unknown, partly by careful experiment, and partly by the prophetic vision of thought. It first discovers facts, and then seeks to interpret them, although oftentimes the interpretation is not capable of absolute proof. So with the material of this article. We have seen that many relations connect in some mysterious way those bodies which we commonly regard as simple, and we have sought to determine their meaning. What can they mean, save that the elements are not elementary? How could the elements have originated but by a process of evolution?

THE NATURE OF FLUORESCENCE.[1]

By Dr. EUGENE LOMMEL,
PROFESSOR OF PHYSICS IN THE UNIVERSITY OF ERLANGEN.

THE question now arises, What becomes of the rays that have undergone absorption? Are they in fact, as they appear to be, annihilated? A series of phenomena now to be considered will give us an answer to these questions.

If water containing a little *esculine*, a substance contained in the bark of the horse-chestnut in solution, be placed in a flask, and the rays of the sun or of the electric lamp, concentrated by a lens situated at about its focal distance from the vesel (Fig. 1), be directed upon it, the cone of light thrown by the lens into the interior of the fluid will be seen to shine with a lovely sky-blue tint. The particles of the solution of esculine in the path of the beam become spontaneously luminous, and emit a soft blue light in all directions. The cone of light appears brightest at the point where it enters into the fluid through the glass, and quickly diminishes in brilliancy as it penetrates more deeply.

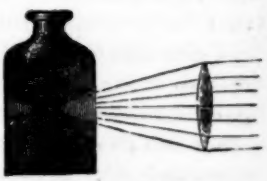

FIG. 1.—ILLUSTRATION OF FLUORESCENCE.

There are great numbers of fluid and solid bodies which become

[1] From "The Nature of Light," No. XIX. of the "International Scientific Series."

similarly self-luminous under the influence of light. This peculiarity was first observed in a kind of spar occurring at Alston Moor, in England, which, itself of a clear green color, appears by transmitted solar light of a very beautiful indigo-violet color. From its occurrence in calcium fluoride the phenomenon has been named *fluorescence.*

In order to understand more precisely the circumstances under which fluorescence occurs, the solution of esculine must again be referred to. The light, *before* it reaches the lens, must be allowed to pass through just such another solution of esculine contained in a glass cell with parallel walls. The cone of light proceeding from the lens, as long as it passes through the air, does not appear to have undergone any material change, it is just as bright and just as white as before. In the interior of the fluid, however, it *no longer presents a blue shimmer, but becomes scarcely perceptible.*

Thus it is seen that light which has traversed a solution of esculine is no longer capable of exciting fluorescence in another solution of esculine. Those rays consequently which possess this property must be arrested by the first solution of esculine. Similar results are obtained in the case of every other fluorescent substance.

The general proposition can therefore be laid down, *that a body capable of exhibiting fluorescence fluoresces by virtue of those rays which it absorbs.*

In order to determine what rays in particular cause the fluorescence of esculine, the spectrum must be projected in the usual way; but, instead of its being received upon a paper screen, it must be allowed to fall upon the wall of a glass cell containing a solution of esculine, that is to say, upon the solution itself, and it must then be observed in what parts of the spectrum the blue shimmer appears. The red and all the other colors consecutively down to indigo appear to be absolutely without effect. The bluish shimmer first commences in the neighborhood of the line *G* (Fig. 2), and covers not only the violet part of the spectrum, but *stretches far beyond the group of lines H* to a distance which is about equal to the length of the spectrum visible under ordinary circumstances.

From this the conclusion must be drawn that there are rays which are still more refrangible than the violet, but which in the ordinary mode of projecting the spectrum are invisible; these are termed the *ultra-violet rays.* They become apparent in the esculine solution because they are capable of exciting the bluish fluorescent shimmer in it. If sunlight have been used in the above experiments, the well-known Fraunhofer's lines appear upon the bluish ground of the fluorescing spectrum, not only from *G* to *H*, but the ultra-violet part also appears filled with numerous lines, the most conspicuous of which are indicated by the several letters *L* to *S* (Fig. 2). That these lines, like the ordinary Fraunhofer's lines, belong properly to solar light, and do not depend upon any action of the fluorescing substance, is

evident from the circumstance that with the electric light they are no more apparent in the ultra-violet than in the other colors, and further, because the same lines are seen in the solar spectrum, whatever may be the fluorescing substance under examination.

Quartz has the power of transmitting the ultra-violet rays far more completely than glass. If, therefore, the glass lens and prism hitherto used for projecting the spectrum be replaced by a quartz lens and prism, the ultra-violet part of the spectrum is rendered much brighter and is extended still farther than before.

FIG. 2.—SOLAR SPECTRUM WITH THE ULTRA-VIOLET PORTION

The ultra-violet rays of the spectrum can, moreover, be seen, without the intervention of any fluorescing substance, through a glass, or, still better, through a quartz prism, if the bright part of the spectrum between *B* and *H* (Fig. 2) be carefully shut off. With feeble illumination its color appears indigo-blue, but with light of greater intensity it is of a bluish-gray tint (lavender). The ultra-violet rays thus ordinarily escape observation, because they produce a much feebler impression on the human eye than the less refrangible rays between *B* and *H*.

An explanation is thus afforded why the solution of esculine, apart from its absorption, is colorless when seen by transmitted light; for, since it absorbs only the feebly luminous violet and the entirely imperceptible ultra-violet rays, the mixed light that has passed through it still appears white, and is not rendered materially fainter.

If the solar spectrum be thrown in the above-mentioned manner upon the fluid, its fluorescing part everywhere exhibits the same bluish shimmer; and spectroscopic examination shows that this bluish light has always the same composition, whether it is excited by the *G* rays, or by the *H* rays, or by the ultra-violet rays, and that it is formed of a mixture of red, orange, yellow, green, and blue. It is thus seen that the different kinds of homogeneous light, as far as they are generally effective, produce *compound* fluorescent light of identical composition, the constituents of which, nevertheless, are collectively *less refrangible than, or are at most equally refrangible with*, the exciting rays.

Among other fluorescing bodies may be mentioned the solution of quinine, which is as clear as water, and has a bright-blue fluorescence; the slightly yellow petroleum, with blue fluorescence; the yellow solution of turmeric, with green; and the bright-yellow glass containing uranium, which fluoresces with beautiful bright-green fluorescence. It admits of easy demonstration that in these bodies also it is

the more refrangible rays that call forth fluorescence. For, if we illuminate them with light which has passed through a red glass, no trace of fluorescence is visible. But, if the red be exchanged for a blue glass, the fluorescence becomes as strongly marked as with the direct solar light. A remarkable phenomenon is presented in the splendid bright-green light which is emitted by uranium glass under the action of blue illumination.

The highly-refrangible rays which possess in so high a degree the power of exciting fluorescence are contained in large proportion in the light emitted by a Geissler's tube filled with rarefied nitrogen. In order to expose fluorescing fluids to the influence of this light, the arrangement represented in Fig. 3 may be employed with advantage. A narrow tube is surrounded by a wider glass tube, into which the fluid is introduced by a side opening which can be closed if required. Another form of Geissler's tube is represented in Fig. 4, which con-

FIG. 3.—GEISSLER'S FLUORESCENCE TUBE.

FIG. 4.—GEISSLER'S TUBE WITH URANIUM GLASS SPHERES.

tains in its interior a number of hollow spheres composed of uranium glass. Where a beam of reddish violet nitrogen light traverses the tube, the uranium glass balls shine with a beautiful bright-green fluorescent light.

The electric light passing between carbon-points is rich in rays of high refrangibility, indeed the ultra-violet end of its spectrum reaches even farther than that of the solar spectrum. In the light of the magnesium-lamp the ultra-violet rays are also abundant, and both sources

of light are therefore particularly well adapted to produce fluorescence, while gas and candle light are nearly inoperative on account of the small amount of the more refrangible rays they contain.

It would nevertheless be incorrect to infer from the above facts that the more refrangible rays are exclusively capable of exciting fluorescence. A red fluid which is an alcoholic solution of naphthaline red, and which in ordinary daylight fluoresces with orange-yellow tints of unusual brilliancy, will serve to demonstrate that even the less refrangible rays are capable of producing this effect. In fact, if the spectrum be projected upon the glass cell containing the fluid (Fig. 5), the yellow fluorescent light will be seen to commence at a point intermediate to *C* and *D*, and therefore still in the red, and to

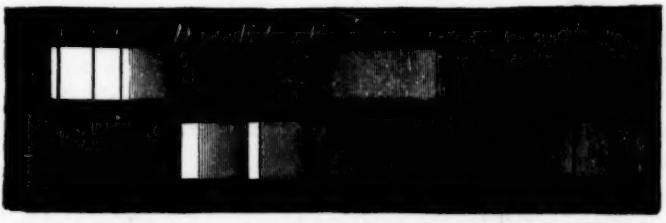

FIG. 5.—ABSORPTION AND FLUORESCING SPECTRUM OF NAPHTHALINE RED.

extend over the whole remaining spectrum as far as the ultra-violet. The strongest fluorescence by far is shown behind the line *D* in the greenish-yellow rays. It then again diminishes, and becomes a second time more marked between *E* and *b*; thence onward the fluorescence becomes fainter, then increases again in the violet, and gradually vanishes in the ultra-violet. In naphthaline red, therefore, there are rays of low refrangibility, namely, the green-yellow rays behind *D*, by which its fluorescence is most powerfully excited.

The fluorescence spectrum received upon the fluid shows, as we have already mentioned, three regions of stronger fluorescence, and the absorption spectrum of naphthaline, which, by placing a small cell filled with the solution in front of the slit, may be obtained upon a paper screen, gives a key to the cause of this phenomenon. In this spectrum Fig. 5 (1), a completely black band is visible in the green-yellow behind *D*, a dark band between *E* and *b*, while the violet end appears shaded. On employing a very strong solution of the naphthaline coloring material, the whole spectrum vanishes with the exception of the red end, which remains apparent to a point behind *C*. If now the absorption spectrum be compared with that thrown upon the fluid, the intimate relation between absorption and fluorescence that has already been pointed out in the esculine solution is corroborated in the minutest particulars. *For every dark band in the absorption spectrum corresponds to a bright band in the fluorescing spectrum.* Every ray absorbed by the fluid occasions fluorescence, and the fluorescent

light produced is the brighter, the more completely the ray is absorbed.

A second example of the excitation of fluorescence by rays of small refrangibility is exhibited by a solution of chlorophyll. The spectrum projected upon this green fluid fluoresces of a dark-red color, from *B* to a point within the ultra-violet, exhibiting at the same time bright bands which correspond with the dark bands in the absorption spectrum. Between *B* and *C*, where the greatest amount of absorption occurs, the fluorescence is also the most marked. But it is the middle red rays which here act so powerfully as excitants. It is remarkable that the red fluorescent light which the chlorophyll solution emits likewise lies, in regard to its refrangibility, between *B* and *C*. Chlorophyll solution affords a proof that all rays of the spectrum, with the exception of the extreme red in front of *B*, are capable of calling forth fluorescence. Their capacity for doing so depends simply on the power of absorption of the fluorescing substance. The most refrangible violet and ultra-violet rays are, however, characterized by the circumstance that they are capable of exciting all known fluorescing bodies.

Fluorescent light is only perceived so long as the fluorescent substance is illuminated by the exciting rays. As soon as the light falling on it is obstructed, the colored shimmer vanishes. It is only in the case of some fluorescing solid substances, as, for example, fluor-spar and uranium glass, that, with the aid of appropriate apparatus (Becquerel's phosphoriscope), a very short continuance of the fluorescence may be observed to take place in the dark.

There are, however, a number of bodies which, after being excited to self-luminosity by a brilliant light, continue to shine for a certain time in the dark. A series of pulverulent white substances, namely, the sulphur compounds of calcium, strontium, and barium (which should be kept in hermetically-sealed glass tubes), do not exhibit the faintest light in a dark room. Moreover, if they be covered with a yellow glass and illuminated with the light of a magnesium-lamp, they remain as dark as before. But if the yellow be exchanged for the blue glass, and the magnesium-light be allowed to play upon them for a few seconds only, they emit in the dark a soft light, each powder having its own proper tint of color. This power of shining in the dark *after having been exposed to the light is called phosphorescence.* The property is possessed in a high degree not only by the above-named artificially-prepared substances, but by various minerals, as the diamond, fluor-spar, and a variety of fluor-spar called chlorophane.

THE CONTROVERSY ON ACOUSTICAL RESEARCH.

TYNDALL ON SOUND.[1]

THE work of Prof. Tyndall on the philosophy of sound has won for itself, in its former editions, the highest possible recognition among scientific men, not only in England, but in other countries. A little more than a year ago, the second edition of this book was translated into German under the special supervision of such eminent investigators as Helmholtz and Wiedemann. In the work before us we have the third revision of the eminent professor's observations under this head. In preparing it, he says, he has subjected the previous edition to a careful reëxamination, and, in so doing, has "amended as far as possible its defects of style and matter, and paid at the same time respectful attention to the criticisms and suggestions which the former editions called forth."

In the preface to this publication it is announced by Prof. Tyndall that the new matter of greatest importance which has been introduced into it is an account of an investigation which during the past two years he has been conducting in connection with the Elder Brethren of the Trinity House. It may not be known to all our readers that what we call our Lighthouse Board at Washington is known in England as "The Trinity House." The title carries us back to the era when monasticism was prevalent in Europe. In its original charter, the body was named "The Masters, Wardens, and Assistants of the Guild, Fraternity, or Brotherhood of the most Glorious and Undivided Trinity, and of St. Clement, in the Parish of Deptford Stroud, in the County of Kent." In the year 1836, an act of Parliament vested in this "Trinity House," as then constituted, the entire control of the lighthouses of England and Wales, and gave it certain powers over the lights in Scotland and Ireland. Prof. Tyndall appears to have entered on his duties as "the scientific adviser" of the Elder Brethren shortly after his return to England at the close of his lecturing tour in the United States in the year 1873. In the seventh chapter of the present volume, under the head of "Researches on the Acoustic Transparency of the Atmosphere in Relation to the Question of Fog-Signaling," he gives the processes and the results of some very interesting observations which he has conducted under the patronage of the British Trinity House. The general results of these observations had already transpired, but in the work before us they have received the professor's definite statement side by side with a narrative of the researches from which they have been deduced. It is to this portion of the volume, containing "the new matter of greatest importance," that we propose to confine our attention in this short review.

[1] From the *Nation* of October 28, 1875.

The reader who turns to this seventh chapter will find that it opens with an "introduction" professing to give "a summary of existing knowledge" in the matter of fog-signaling. The writer states that while the *velocity* of sound has formed the subject of repeated and refined experiments by the ablest philosophers, "the publication of Dr. Derham's celebrated paper in the 'Philosophical Transactions' for 1708 *marks the latest systematic inquiry into the causes which affect the intensity of sound in the atmosphere.*" And, after making this statement, the professor immediately adds as follows: "Jointly with the Elder Brethren of the Trinity House, and as their scientific adviser, I have recently had the honor of conducting an inquiry designed to fill *the blank here indicated.*" In order still further to impress on the reader a sense of the magnitude of this "blank," Dr. Tyndall indulges in one or two preliminary references which, he says, "will suffice to show the state of the question when this [his] investigation began." The first of these references cites the opinion of Sir John Herschel to the effect that fogs and falling rain, and more especially snow, had been found by Derham "to tend powerfully to obstruct the propagation of sound." The second of his references is made to what he calls "a very clear and able letter" addressed by Dr. Robinson, of Armagh, to the British Board of Trade in 1863. In this "very clear and able letter" Dr. Robinson states that sound is the only known means for coping with fogs, but about it, he adds, "the testimonies are conflicting, *and there is scarcely one fact relating to its use as a signal which can be considered as established.*" But Dr. Robinson is clear on one point—to wit, that "fog is a powerful damper of sound."

On the strength of these historical references, Dr. Tyndall ventures the remark that, prior to the investigation conducted by him, the views enunciated under this head by Derham, Herschel, and Robinson, "were those universally entertained." It was in order to fill "the blank" indicated by the universal prevalence of such erroneous opinions that *his* inquiry, he says, was set on foot. And his inquiry, he tells us, was begun May 19, 1873.

Now, it is a matter, not only of scientific knowledge, but of public notoriety in this country, that extensive researches on "the causes which affect the intensity of sound in the atmosphere" had been made by the United States Lighthouse Board long before Prof. Tyndall began his investigations. That he should have chosen to ignore the fact in the body of his present volume becomes only the more surprising when, on turning to its preface, we find that he was, as he confesses, "quite aware *in a general way* that labors, like those now for the first time made public, had been conducted in the United States," and "this knowledge," he subjoins, "was not without influence upon my conduct." If his knowledge of the similar labors conducted under this head in the United States was not, as he acknowl-

edges, without influence on his conduct in giving direction to his researches, it will naturally occur to ordinary minds that this knowledge should also have been "not without influence" on his pen when he was professing to give a summary of the existing state of science on this subject. And when to this statement of the case, as acknowledged by himself, we add that he was made acquainted with the nature and purport of Prof. Henry's explorations on this question, not only "in a general way," but also in a very special way, it becomes still more inexplicable that, in defining "the blank" which he claims to have filled by his recent inquiry, he should have disregarded the labors and results of American science, and that, too, while profiting by the instruments and methods of that science in the very conduct of his investigations. The reader will understand the force of our remark that Prof. Tyndall was acquainted with the researches of Prof. Henry, not only "in a general way," but also in a special way, when we state that a paper by the latter—on the abnormal phenomena of sound in relation to fog-signaling—was read by its author in the hearing of Prof. Tyndall at a meeting of the Washington Philosophical Society, called for the purpose of doing honor to the British *savant* while he was sojourning in the national capital. And the force of our remark that he has ignored the results of American science in magnifying "the blank" which he describes, while profiting by the instruments and methods of that science in conducting his inquiry, will be understood when we say that the researches of Prof. Tyndall were prosecuted with the help of a steam-siren, gratuitously lent to him by the Lighthouse Board at Washington, constructed and patented by a citizen of New York, and introduced by Prof. Henry into the lighthouse system of the United States.

We are now prepared for the next stage of this review. It so happened that while Prof. Tyndall was conducting his researches on sound in relation to fog-signaling, an officer of the United States Corps of Engineers, Major Elliot, had been deputed by the Lighthouse Board at Washington to make a tour of inspection in Europe, with instructions to report upon matters relative to lighthouse apparatus and the management of lighthouse systems. Major Elliot reached London a few days before Prof. Tyndall began his experiments at Dover, and was courteously invited to be present, but for want of time was compelled to forego the privilege. The results of the English experiments were, however, subsequently communicated to Major Elliot by Sir Frederick Arrow, the Deputy Master of Trinity House (who, we are sorry to say, has since deceased), and were embodied in his report on the "European Lighthouse Systems," as recently published. The publication of Major Elliot's report was accompanied, in the annual report of the United States Lighthouse Board for the year 1874, with the following observations:

"Major Elliot gives a detailed account of a late series of experiments by the

Trinity House Board on fog-signals. Now, although this account is interesting in itself to the public generally, yet, being addressed to the Lighthouse Board of the United States, it would tend to convey the idea that the facts which it states were new to the board, and that the latter had obtained no results of a similar kind; while a reference to the Appendix to this report *will show that the researches of our Lighthouse Board have been much more extensive on this subject than those of the Trinity House, and that the latter has established no facts of practical importance which had not previously been observed and used by the former.*"

The "Appendix" here referred to is from the pen of Prof. Henry, the chairman of the board, and details elaborate experiments on sound in relation to fog-signaling, as pursued in the service of the United States Lighthouse Board since the year 1855. Brought to book by this "Appendix," Prof. Tyndall asks his readers, in the preface of the present edition of his volume, to bear in mind that "the Washington Appendix was published nearly a year after his [my] report to the Trinity House." But in so writing it seems to have escaped his notice that in a subsequent part of this same preface he has confessed that he was "quite aware in a general way" that labors like his own had been conducted in the United States, and that "*this knowledge was not without influence on his conduct.*" And in so writing he forgets, too, that he was an interested listener to the paper read by Prof. Henry on this subject in his hearing while he was in the United States, and before he had turned any attention at all to the phenomena of sound in connection with fog-signals. He states in the body of his book, as already mentioned, that his inquiry under this head began on May 19, 1873, several months after his "general" and his special knowledge of what had been accomplished in this country. And yet, in the face of all these facts and acknowledgments he has allowed his "summary of existing knowledge" on the subject to stand without any recognition of American science in the premises —a suppression which does as little credit to his scientific generosity as to his literary art, for he can be convicted of delinquency in respect of the former by the inconsistency of statement into which he has fallen through a want of dexterity in the latter.

We may, therefore, safely leave the acknowledged record to substantiate the claims of the United States Lighthouse Board when they represent that their researches, running through many years, "are much more extensive on this subject than those of the Trinity House." It remains for us only to consider the second branch of their representation—namely, that the latter (the Trinity House) "has established no facts of *practical importance* which had not been previously observed and used by the former (the United States Lighthouse Board)." In support of this statement we may point to the fact that Prof. Tyndall nowhere pretends to have established by his researches any improvements whatsoever on the methods or instru-

ments of fog-signaling as practised in the United States. On the contrary, he acknowledges that in the choice of fog-signals for British use his "strongest recommendation applies to an instrument for which we are indebted to the United States." He will remember, moreover, that while he was sojourning in the United States he sought and obtained opportunities from Prof. Henry to observe the operation of the steam-siren in the lighthouse at Sandy Hook. At that time, if not before, he was made acquainted with the progress not only of American science but also of American art under this head. And in view of the fact that, as the "scientific adviser" of the Elder Brethren of the Trinity House, he has counseled them to discard their English horns and whistles and to substitute for them the steam-sirens which have been, for several years, in the use of our American lighthouses, it would seem that the second branch of the claim advanced by the board at Washington stands in as little need as the first of any additional reënforcement at our hands. Bacon rejoiced in the fact that his philosophy was a philosophy which brought forth fruit in the service of man. The progress of American science in this department has been constantly bearing fresh fruit in the interests of commerce and for the relief of the mariner. Daboll's trumpet, an American invention, came to supersede the use of gongs, and bells, and horns, and guns. To-day the steam-siren, an instrument devised and perfected under the direction of the United States Lighthouse Board, is acknowledged to be without a rival as an efficient fog-signal.

It is no part of our present purpose to institute a critical inquiry into the conflicting views of Prof. Henry and of Prof. Tyndall with regard to the hypotheses respectively espoused by each for the explanation of the phenomena of sound in its passage through wide tracts of air. Prof. Henry believes that the direction and the rate of wind-currents are important elements in the problems presented by the phenomena in question. Prof. Tyndall admits that "the well-known effect of the wind is exceedingly difficult to explain," but he insists on making up the fagot of his scientific opinions on the subject at once and forever without taking the "viewless winds" into his account. He finds a sufficient explanation of all the abnormal phenomena in the assumption of ideal clouds of vapor mingling with the atmosphere so as to disturb its homogeneity, and thereby to quench the body of sound. There is nothing in the working hypothesis of Prof. Henry which excludes any truth there may be in the working hypothesis of Prof. Tyndall. But, in the present provisional state of his inquiries on the subject, the former is disposed to question the sufficiency of the explanation adduced by the latter as an efficient cause of all the phenomena in question. With the modesty and reserve of the true physical philosopher, in the present unfinished state of scientific inquiry, Prof. Henry waits for the wider knowledge which

shall furnish the basis of an assured induction meeting all the requirements of the problem.

Prof. Tyndall, however, is impatient of any contradiction. He admits that he has not verified the effect of wind-currents "by means of a captive balloon rising high enough to catch the deflected wave," but none the less he ventures to propound his hypothesis as the last word of science in the premises. Indeed, he takes great credit to himself for having been able to rise above "the authority" of Prof. Henry in this investigation. He says that in one of his "phases of thought" on the question he passed through the solution "which Prof. Henry now offers for acceptation," "weighed it in the balance," and "found it wanting." And, as if this language were not supercilious enough, he proceeds to indulge in the following self-complacent reflections:

"But though it [Prof. Henry's solution of ocean-echoes] thus deflected me from the proper track, shall I say that *authority in science is injurious?* Not without some qualification. It is not only injurious, but deadly, when it cows the intellect into fear of questioning it. But the authority which so merits our respect as to compel us to test *and overthrow all its supports*, before accepting a conclusion opposed to it, is not wholly noxious. On the contrary, the disciplines it imposes may be in the highest degree salutary, though they may end, *as in the present case, in the ruin of authority.*"

It is impossible to conceive of language more expressive of vanity, conceit, and arrogance, than this ascription of intellectual superiority to which Prof. Tyndall treats himself on the assumption that he has laid "the authority" of Prof. Henry in "ruins" upon the question of atmospheric sound. At no time and in no place has Prof. Henry assumed to speak "by authority" on the subject. The man of straw whom Tyndall sets up under cover of Henry's name, in order to exhibit upon it the strength and prowess of his intellectual muscle, is a cheap device of rhetoric which a much inferior man might have disdained to employ in a case like this. The cause of science does not profit by the self-laudation of its votaries, and Prof. Tyndall's praises are in the mouths of too many people to render it necessary for him to praise himself at the expense of Prof. Henry or of anybody else.

REPLY OF PROFESSOR TYNDALL.[1]

To the Editor of the Nation.

SIR: I have been favored with a copy of the *Nation* of October 8th, and would ask permission to make a few remarks on the *critique* of my work on "Sound" therein contained.

With regard to Prof. Henry, I hope I am not presumptuous in venturing the opinion, and expressing the belief, that his earlier scientific labors were marked by rare power and originality, and that his later years have been usefully and honorably employed in the service

[1] From the *Nation* of December 23, 1875.

of his country. Such, if I dare say so, are the sentiments which I have ever expressed regarding Prof. Henry here and elsewhere.

When I first learned that he was in danger of falling into what I considered to be grave scientific error, I went as far as friendliness dared go to avert it. I addressed to him a private letter, in which I tried to impress upon him the completeness and conclusiveness of the evidence which he seemed disposed to call in question. He did not honor that letter with any notice, preferring to discuss the subject publicly in the "Report of the Washington Lighthouse Board." He was clearly within his right in doing so; but I submit that I only exercised my right when I met him on ground thus chosen by himself.

No English gentleman that I have consulted can discern in what I have written any violation of the dignity of scientific debate; but your article would lead to the inference that I had both violated common honesty and taken leave of common-sense. I will not quote your words, because I cherish the hope that when you have reflected on them you will regret them. When I say "you," I mean the editor of the *Nation*, whose acquaintance I had the honor to make, and whose kindness I had the privilege to experience, in New York—I do *not* mean the writer of the article. Let me respectfully assure you, then, that, when I spoke of being "deflected by authority," "Prof. Henry's solution of ocean-echoes" was not at all in my mind, nor his "ruin," partial or total, in my calculations. Consider, I pray you, how impossible it is that this could have been the case. The "deflection" spoken of is expressly described as occurring at the outset of an investigation begun in May, 1873, *whereas the Washington report containing Prof. Henry's solution of ocean-echoes is the report for* 1874, *which did not reach Europe until the spring of* 1875. This, then, is the crumbling foundation on which your critic builds his odious charge. In verity, the remark on which he pours his peroratory invective was not meant for "laudation" of any kind, but merely to show the "polar" character of authority—its good side and its bad.

It is easy, as you know, Mr. Editor, to sneer and to assail; but less easy to show, without going into details not worth the labor, that the sneer is unmeaning, and the assault unfair. Nevertheless, the broad lines on which, in the present instance, I would meet my anonymous assailant may, I think, be made clear. He industriously mixes together things which ought to be kept apart—experiments on fog-signals and inquiries into "the causes which affect the transmission of sound through the atmosphere." The "blank" which I proposed to fill is stated, with unmistakable clearness, to have reference solely to such "causes." Neither Herschel nor Robinson, as far as I know, ever made an experiment on fog-signals; still I quote them. Why? Because they are the most eminent and authoritative exponents of the theories of acoustic opacity which up to last year were entertained

by the highest scientific minds. Theirs, moreover, and Arago's (not Prof. Henry's), was the "authority" which "deflected" me at first. Apart from the wind, the "causes" of acoustic opacity indorsed by these eminent men were rain, hail, snow, haze, and fog—everything, in short, that affected the optical clearness of the atmosphere. Prior to the South Foreland investigation, where, I would ask, is a "systematic inquiry" into these causes to be found? Surely, if such an inquiry has been published, it can be courteously pointed out and calmly discussed. If you can prove its existence you will have the right to demand from me the very fullest apology and reparation for stating that "no such systematic inquiry had to my knowledge been made." Even then I could not charge myself with untruth; for my "knowledge" was, and is, arithmetically what I have affirmed it to be; but I can confess ignorance and express regret.

Give me your patience while I endeavor still further to make this matter clear. As regards the invention of instruments and their practical establishment as fog-signals, so far was my knowledge behind "the science of the United States," that I had never seen or heard one of those great steam-whistles until I met them at the South Foreland. The common "siren" is well known to have been a familiar instrument with me, but the fog-signal I first saw and heard upon its native soil in America—not, however, as your critic puts it, but at the request, twice repeated, of Prof. Henry. Further, to the best of my recollection, prior to the month of May, 1873, I had only heard one or two experimental blasts from a fog-trumpet. In such work, then, I had neither part nor lot; and, if you will permit me to say so, though it is of the utmost practical value, I should hardly label such work with the name of "science." Quite apart from those practical achievements lies the inquiry into "the causes which affect the transmission of sound through the atmosphere." And, if I except the sagacious remark of General Duane which has been so curtly brushed aside, not a scintilla of light has been cast upon these causes by any researches ever published by the Lighthouse Board of Washington.

Will you allow me to say, in passing, that Major Elliot, the able and conscientious officer whose excellent "Report on the Lighthouses of Europe" was so displeasing to the board, *did* accept the invitation to Dover, and that to the present hour I feel indebted to him for the information and advice given to me at the time?

Upon my "conduct" and the knowledge which "influenced" it, your critic rings the changes of his wit. It is, after all, a very simple and straightforward matter. The "conduct" consisted in my emphatic advice to the Elder Brethren of the Trinity House not to confine themselves to home-made apparatus, but to include American ones in their inquiry. The subsequent trial led to the abandonment of the English instruments, and the adoption of others from Canada and the United States. The *siren*, for example—which your critic erroneous-

ly says was lent "gratuitously" to *me*[1]—was paid for in February, 1874, and two others are at this moment on their way from New York to England. Both by word and deed have we acknowledged our real obligations to the United States; but what we did not and could not acknowledge (for it was non-existent) was, any solution of the conflicting and anomalous results obtained with these fog-signals—results so conflicting and so anomalous as to cause reflecting minds to entertain doubts as to the capacity of the observers. Apart from the friendship shown to me at the time, all that I remember of the meeting at Washington, to which your critic refers, is the utter perplexity of everybody present, myself included, in regard to the matter in hand. I had my guess—others had theirs; but we were quite at sea in our guesses, without a signal to guide us through the intellectual fog.

Knowing, indeed, the difficulty of the subject, when its investigation was first proposed to me by the Elder Brethren, I shrank (as Faraday had done before me) from a work of such obvious labor and such uncertain scientific promise. Doggedly, however, we attacked it, determined to go through the mechanical processes already followed by others, even if they led, as regards science, to an equally barren result. Out of the darkness at length came the dawn. We prolonged our investigations until they embraced every agent, save one, to which influence had been previously ascribed. The exception was snow. This, however, was directly met by observations made upon the *Mer de Glace* in the bitter winter of 1859, and which have been entirely confirmed by the later observations of General Duane. Having negatived antecedent theories, we wrought our way positively to the basis of the whole question. This we found in a cloud-world, invisible to the eye of sense, but as visible and certain to the mental eye as the ordinary cloud-world of our atmosphere. The lights and shadows of these "acoustic clouds"—the action of which must, at one time or another, have been noticed by every peasant within range of a peal of bells—sufficed to account for the most astounding variations of intensity. This, I say, has been established, not only by patient and long-continued observations afloat, but by laboratory experiments as indubitable as any within the range of physical science.

And, let me add, it was neither whistles nor trumpets, nor yet the siren, which pointed out the way to this solution, but experiments with *guns* ably served by artillerymen from Dover Castle.

I will not make any further draft upon your generosity, though, were it worth while to do so, other fallacies of fact and logic in your critic's article might be exposed. He says, or intimates, for example, that I became "adviser" to the Trinity House after my "lecturing tour in the United States in 1873." I relieved Michael Faraday of this duty in May, 1866. My friends in New York have already had

[1] It was lent to the Trinity House Corporation; and I expressly signalize the lending as "an act of international courtesy worthy of imitation."

to disperse other delusions regarding the "profits" of that "tour." Such statements are credible to the mean, incredible to the high-minded, and were therefore never thought worthy of refutation by me. And why should I now waste a word upon your critic's closing sentences? It will not make him noble to be told that envy is ignoble; that, if ever "praise" has been adjudged to me by his countrymen, it is not because I went out of my way to seek it. It came to me unasked—an incident, not an aim—shining, as your own Emerson would put it, pleasantly because spontaneously, upon the necessary journey of my life. It was not, I can truly say, the applause of large assemblies that constituted my chief happiness in the United States, but the ever-growing proof, for the most part undemonstrative, that, without swerving from my duty, I had gained a modicum of the affection of the American people. *That* I prized, and *that* I have sought to keep free from fleck, material or intellectual. For reasons best known to himself, your critic does not relish this relation; and he will damage it if he can. I cherish the belief that he will be unsuccessful. I have the honor to be, your obedient servant,

JOHN TYNDALL.

LONDON, *November* 23, 1875.

SKETCH OF THOMAS STERRY HUNT, LL. D., F. R. S.

THE subject of the present notice, of whom an excellent portrait appears in this number, although still in middle life, has made extensive contributions to American science during the past generation, and has permanently identified his name with its progress and development. Choosing two of the most rapidly-advancing sciences, chemistry and geology, as his field of work, and studying them especially in their intimate and extensive interactions, he has had a large and honorable share in giving form to our present knowledge upon these subjects. Although an indefatigable experimenter and an extensive observer, Dr. Hunt is also eminently an original and philosophic thinker, and has taken an influential part in the establishment of the most matured scientific theories. He was early in the field of chemical speculation, and aided essentially in that revolution of views which has ended in the establishment of the "new chemistry."

THOMAS STERRY HUNT was born on the 5th of September, 1826, in Norwich, Connecticut, where he received his early education. He began the study of medicine, but soon abandoned it for chemistry and mineralogy, and in 1845 became a private student with the present Prof. Benjamin Silliman at New Haven, acting meanwhile as chemical assistant to Prof. B. Silliman, senior, in the chemical laboratory of

Yale College. In 1847, while preparing to continue his studies in Great Britain, he was chosen to be chemist and mineralogist to the Geological Survey of Canada, then recently established under the direction of Sir William Logan, and having its headquarters at Montreal. This position he held for twenty-five years, resigning it in 1872. He was, during this time, for several years a professor in the Laval University at Quebec, where he lectured on chemistry and geology in the French language, and was afterward Professor of Chemistry and Mineralogy at McGill University, Montreal. Coming to Boston in 1872 he took the chair of Geology in the Massachusetts Institute of Technology, made vacant by the resignation of Prof. William B. Rogers, a post which he still occupies. He has never married.

His earlier scientific labors were chiefly in the domain of chemistry. Prof. B. Silliman, in his "History of American Contributions to Chemistry," which appeared in the "Proceedings of the Centennial of Chemistry" (*American Chemist* for 1874), says:

"The name of no American chemist occurs more frequently, or in a more important relation to the progress and development of our science during the past quarter of a century, than that of Dr. Hunt. His contributions have been equally valuable in theoretical chemistry, in chemical philosophy, and in geological and mineralogical chemistry. No other author has covered a wider range than he. Not less than one hundred and thirty entries are found under his name in the second and third series of the *American Journal of Science*, and adding those published in Canada, England, and France, and some memoirs in the proceedings of various American societies, the total roll of his papers amounts to about one hundred and sixty titles."

A considerable proportion of these, however, relate to pure geology.

From the "History" just quoted, and from a biographical notice in THE AMERICAN CYCLOPÆDIA, we learn of Dr. Hunt's important contributions to theoretical chemistry, and his attempts to introduce into the sciences of chemistry and mineralogy a new philosophy, some points of which will be found in his address in 1874, at the Centennial of Chemistry at Northumberland, Pennsylvania, entitled "A Century's Progress in Chemical Theory." His papers on these subjects were widely copied and translated, and have greatly influenced modern chemistry. At an early date Dr. Hunt prepared a summary of organic chemistry, which he first defined to be the chemistry of carbon and its compounds, and which forms a part of Silliman's "First Principles of Chemistry" (1872). A statement of some of the aspects of the science will be found in the last annual address before the Massachusetts College of Pharmacy, delivered by him, on "The Relations of Chemistry to Pharmacy and Therapeutics" (Boston, 1875); and we present an abstract of this in the present number. It is said of Dr. Hunt, in the notice above referred to, that his researches on the chemistry of soda and mineral waters have probably been more extended than those of any other living chemist. These have been both syn-

thetic and analytic, and we owe to him elaborate studies of the chemistry of lime and magnesia, undertaken with reference to the origin of the native combinations of these bases. Mention should also be made of his contributions to a chemical cosmogony and to a comprehensive theory of chemical and dynamical geology, a sketch of which will be found in his essay on "The Chemistry of the Earth," in the "Smithsonian Report" for 1869.

Dr. Hunt's numerous contributions to chemistry and geology in their technical applications relating to soils, fertilizers, peat, building-materials, the manufacture of salt, and the ores and metallurgy of iron and copper, will be found in the publications of the Geological Survey of Canada, and in part in the proceedings of the Institute of Mining Engineers. *See* also his essay on "The Coal and Iron of Southern Ohio" (Salem, 1874). A large part of the reports of the Canada Survey during twenty-five years was contributed by him, and also the latter half of the large volume entitled "Geology of Canada" (1863).

Among Dr. Hunt's later contributions to geology are his studies of "Granites and Granitic Veinstones;" "The Geognosy of the Appalachians and the Origin of Crystalline Rocks" (1871); and the "History of the Names Cambrian and Silurian in Geology" (1872). His views as to the crystalline, stratified rocks, their genesis, their great antiquity as opposed to the notion of their more recent origin, and his grouping and classification of them, undertaken after many years of research and comparison over a wider field than has been studied by any other American geologist, constitute a new departure in the science. They have attracted much attention, and, despite some attacks, are finding a wide recognition, both in this country and in Europe. The three essays just named, together with some others, on various subjects of chemical geology, including mineral waters, dolomites, gypsum, petroleum, and ore-deposits, with many notes and additions, and with selections from his papers on the philosophy of chemistry and mineralogy, have lately been published in a volume entitled "Chemical and Geological Essays" (Boston, 1875). Of this work a notice appeared in THE POPULAR SCIENCE MONTHLY, vol. vi., p. 372. It is understood that he is now preparing a "Handbook of American Geology." During the past summer he has been engaged in the new Geological Survey of Pennsylvania under Prof. Lesley.

Dr. Hunt was President of the American Association for the Advancement of Science in 1870. He is a member of the National Academy of Science, the American Philosophical Society, and the American Academy of Boston. In 1859 he was elected a Fellow of the Royal Society of London. He is a member of the Imperial Leopoldo-Carolinian Academy of Germany, and of the Geological Societies of France, Belgium, Austria, Ireland, etc. He was a member of the International Juries at the Great Expositions at Paris in 1855 and 1867, and on the latter occasion was made an officer of the Legion of Honor.

EDITOR'S TABLE.

SOUNDING A NEWSPAPER FOG.

THE readers of the MONTHLY will find elsewhere in our pages an article which appeared several weeks ago in the *Nation*, containing an attack upon Prof. Tyndall, which, from the character of its charges, and the bitterness of its tone, excited the surprise and regret of many. It was replied to by Prof. Tyndall, whose letter we also republish. It will be seen that the assault is directly met, and, in his rejoinder to Prof. Tyndall's letter, the writer in the *Nation* admits that he was in error, while his admission covers the main and most offensive imputations. But, as his further comments are calculated to continue a false impression, and as base charges always go faster and farther than their retractions, especially when considerable time elapses before they can be authoritatively contradicted, it is desirable that we should here briefly review the leading features of the case.

The charge against Prof. Tyndall, as the reader will see, is generally, that, in the third and recently-published edition of his work on "Sound," he has not done justice to the contributions of American science toward the elucidation of the subject of fog-signals. More specifically it is that, when in this country, he got information upon the subject from a paper read by Prof. Henry, went home and entered upon the investigation himself, published in his book the results of his own inquiries, and, while acknowledging that he knew generally of what had been done in America, and that it was not without influence on his conduct, yet that he ignored or "suppressed" from his summary of existing knowledge upon the subject any recognition of what had been accomplished by the United States Lighthouse Board under the direction of Prof. Henry.

Now, let us see what Prof. Tyndall's position was as avowed by himself in a statement widely published in this country months before the attack in the *Nation* was made. The August number of THE POPULAR SCIENCE MONTHLY contains, in full, the preface to the third edition of "Sound," in which the American relations of the matter are considered. A summary is there given of the experiments of Prof. Henry in regard to the penetration of fog by sound, and the performance of various instruments of American construction designed to be used as coast-signals; and the remark is added that "it is quite evident from the foregoing that, in regard to the question of fog-signaling, the Lighthouse Board of Washington have not been idle." Prof. Tyndall states, furthermore, that he had recommended American instruments for fog-signaling to the British authorities as superior to the English instruments, and that they had been adopted on his recommendation. Every fair-minded reader, upon perusal of that paper, will agree, we think, that Prof. Tyndall wrote truthfully when he said: "In presence of these facts it will hardly be assumed that I wish to withhold from the Lighthouse Board of Washington any credit which they may fairly claim."

But, having thus testified to the character, extent, and importance of American work upon this subject, Prof. Tyndall proceeds to state what in his opinion the Lighthouse Board has failed to do. He says: "My desire is to be strictly just; and this desire compels me to express the opinion that their report fails to establish the inordinate claim made in its first paragraph. It

contains observations, but contradictory observations; while, as regards the establishment of any principle which should reconcile the conflicting results, it leaves our condition unimproved."

A distinction is here drawn, and again recognized in his letter, that goes to the root of the subject; the distinction, namely, between experiments on fog-signals made for direct purposes of utility, and similar experiments conducted with a view to the establishment of scientific principles. This discrimination is all-important. It is no doubt possible to have both objects more or less in view in such an inquiry; but it is also possible that either may so predominate as to characterize the respective courses of investigation, and yield very dissimilar results. Elaborate experiments may promote practical ends, and contribute little or nothing to science; or they may advance scientific knowledge without any immediate influence upon practice. It was claimed by Prof. Henry, in his Appendix to the report of the Lighthouse Board for 1874, that the researches of the board had been more extensive on this subject than those in England, as well as prior to them; but the question remains, To what purpose were they carried on? The answer to this question, defining the character and object of the inquiries, is immediately given in the statement that the American results of "practical importance" are in advance of the English. The writer in the *Nation* speaks of "American science" as bearing Baconian fruit, such as Daboll's trumpet and Brown's steam-siren. These devices and construction are, no doubt, highly important, but there is certainly a wide difference between the invention of whistles and systematic inquiries into the causes of acoustical phenomena. No one doubts the immense value to the country and to civilization of the labors directed by Prof. Henry, as chairman of the Lighthouse Board; but he has himself declared their practical character, and how broadly true is this characterization appears from a passage in a letter which he wrote to the Secretary of the Treasury, dated February 22, 1875, defending the Washington board against an attack made upon it in Congress. It is noteworthy, also, as showing that, when Prof. Henry wishes to protect himself from adverse criticism, he falls back upon the verdict pronounced by Prof. Tyndall in this very matter of fog-signals. Prof. Henry said: "The board has a standing committee on experiments which has accepted and sought to test every invention that could be supposed to aid the mariner. Many illuminants, various devices in engineering, expedients for floating aids, plans, and theories of all kinds, have received its attention. To this accusation can be opposed on behalf of the board the verdict of foreign nations, the tributes of scientific associations, and the contented judgment of maritime and commercial men from whom no complaints are received. Its buoys are excellent in their construction; its buoy-service is well performed; its light-ships are equal to any in the world; its lights are entirely satisfactory to the commercial and nautical men for whose interest they are maintained; and its fog-signals surpass, in the finding of Prof. Tyndall, who conducted a series of experiments for the Trinity House Board, those of all other nations, and have been adopted for England." But it is claimed that Prof. Henry's investigations constitute also an important contribution to "American science," in relation to fog-signaling. Prof. Tyndall denies that they have at all advanced our scientific knowledge upon the subject, and the writer in the *Nation* had this denial before him when he wrote. It was his plain business, then, to disprove it if he could, and give the evidence that Prof. Tyndall was in error.

The simple question is, What new scientific principles have been established, or what causes elucidated by

Prof. Henry's investigations, constituting an advance of scientific knowledge in this branch of acoustics, that Prof. Tyndall has omitted or "suppressed" in his work? If any thing has been accomplished in this country toward the scientific solution of such acoustical problems in relation to fog-signaling—if any new light has been cast upon the phenomena that explains anomalies and reconciles contradictions, which was not acknowledged by Prof. Tyndall in his book—we submit that it was the obvious duty of the writer in the *Nation* to point out what it was. He should have indicated the gap in Prof. Tyndall's summary of the present state of knowledge, or he should have shown us what principles or results, there stated, are due to American research. He says: "It is no part of our present purpose to institute a critical inquiry into the conflicting views of Prof. Henry and of Prof. Tyndall with regard to the hypotheses respectively espoused by each for the explanation of the phenomena of sound, in its passage through wide tracts of air." Yet the whole question turns on the scientific "views" contributed by Prof. Henry which it is alleged that Tyndall has ignored. He speaks of the views "respectively espoused" by the parties; but the question is on the views *originated*. Prof. Henry is understood to adopt the theory propounded by Prof. Stokes at the British Association in 1857, according to which sound-waves are tilted through the air under the influence of wind. That theory is certainly not "suppressed" from the new edition of "Sound." In his rejoinder to Prof. Tyndall's letter, the *Nation's* critic reaffirms his assertion, saying, "The question between us is not one of *science*, but of *historical fact*." But his complaint in the first article was certainly of the non-recognition of "American science." Obviously Prof. Tyndall had to decide what is science and what is not, which looks to us very much like a scientific question. In his "summary of existing knowledge," it was not his business merely to chronicle experiments. He had to deal only with such systematic inquiries into causes as yield results properly entitled to take their place in the body of scientific knowledge. We do not say that Prof. Henry's researches have failed to extend the domain of positive scientific knowledge, but only that the writer in the *Nation* was bound to establish this, before accusing Prof. Tyndall of delinquency in not recognizing it.

But it is the closing passage of the *Nation's* article which has excited the greatest surprise, betraying, as it obviously does, a vicious state of feeling on the part of the writer. He there represents Prof. Tyndall as having claimed to demolish the authority of Prof. Henry, and as swaggering over the "ruin" he had accomplished. In half a dozen lines, Tyndall is accused of "superciliousness," "self-complacency," "vanity," "conceit," "arrogance," and "self-laudation;" and this upon an utterly false and absurd interpretation of some incidental remarks in his preface. The following is the passage that called forth this storm of offensive epithets:

"The clew to all the difficulties and anomalies of this question is to be found in the aërial echoes, the significance of which has been overlooked by General Duane, and misinterpreted by Prof. Henry. And here a word might be said with regard to the injurious influence still exercised by authority in science. *The affirmations of the highest authorities, that from clear air no sensible echo ever comes, were so distinct, that my mind for a time refused to entertain the idea.* On the day our observations at the South Foreland began, I heard the echoes. They perplexed me. I heard them again and again, and listened to the explanations offered by some ingenious persons at the Foreland. They were an 'ocean-echo;' this is the very phraseology now used by Prof. Henry. They were echoes 'from the crests and slopes of the waves;' these are the words of the hypothesis which he now espouses. Through a portion of the month of May,

through the whole of June, and through nearly the whole of July, 1873, I was occupied with these echoes; one of the phases of thought then passed through, one of the solutions then weighed in the balance and found wanting, being identical with that which Prof. Henry now offers for solution.

"But though it thus deflected me from the proper track, shall I say that authority in science is injurious? Not without some qualification. It is not only injurious, but deadly, when it cows the intellect into fear of questioning it. But, the authority which so merits our respect as to compel us to test and overthrow all its supports before accepting a conclusion opposed to it, is not wholly noxious. On the contrary, the disciplines it imposes may be in the highest degree salutary, though they may end, as in the present case, in the ruin of authority. The truth thus established is rendered firmer by our struggles to reach it."

A correspondent of the *Nation* from Baltimore, quoting the above passage, characterizes the "glaring injustice" of the concluding portion of its article, and adds: "Any candid reader can see that the passage on which your reviewer bases such serious imputations cannot possibly bear the interpretation which every one reading it as given in your review is compelled to put upon it. Prof. Tyndall never indicates that it was the authority of Prof. Henry that impeded him in his researches." The sentence italicised in the extract upon the previous page is perfectly conclusive in showing what Prof. Tyndall did mean by the authority which embarrassed him until he rejected it.

In his letter Prof. Tyndall puts an end to the charge, so that the *Nation* is compelled to acknowledge itself "in error in supposing that the claim of Dr. Tyndall to have ruined authority was aimed at Prof. Henry." One would think that, when the *Nation's* critic had been convicted of blundering by a correspondent, and when his fabric of detraction had been so effectually demolished by Prof. Tyndall himself that the writer was compelled to back out of it, he would have had the grace to drop the subject. But, on the contrary, he renews the insulting imputation. Having made a slanderous charge entirely upon the assumption that Prof. Tyndall was exulting in the ruin of Prof. Henry's authority, and having barbed his article with this libel, when it was swept away, he says: "It would have been more in order for him to show the propriety of his language in claiming to have 'ruined' the 'authority' of any one among his scientific predecessors, for it was on the alleged self-conceit implied in such a claim as made by himself that we based our 'peroratory invective.'"

Now, we aver that there is nothing in the passage quoted that is open to the offensive construction here put upon it, and which never would have been thought of, but for the unscrupulous distortion of its meaning by the *Nation's* critic; but that the real import of the extract is entirely contrary to that which has been ascribed to it. That which was written to enforce the lesson of cautious self-examination and circumspection in dealing with the mental difficulties of scientific research is wrested into an opposite expression of arrogance and self-conceit. It is not to be forgotten, here, that the scientific man, to the extent of his originality and power, is a questioner of things established. His attitude is that of an enemy of authority. It is his recognized business, as evinced by the common forms of speech, to "subvert" authority, to "break down" authority, to "overthrow," "crush" and "ruin" authority. Call the motive which impels the man of science what you please, the fact remains that in virtue of his being a man of science, aiming to arrive at new views, he is a destroyer of authority. But just because this is his necessary work he is in danger from the state of mind it produces; and it becomes important not to forget that there is good as well as bad in authority. Prof. Tyndall simply intimated the need there is that the inquirer should

be on his guard. Every one familiar with his writings is aware that he differs from most of his scientific colleagues by looking habitually from the subject he is investigating to the working of his own mind in the investigation, and by frequently throwing parenthetical remarks of a philosophical, rather than of a strictly scientific significance, into his expositions. The interjected observations about authority in the preface are clearly of this kind. In his "Lectures on Light," second edition, page 80, he remarks: "Newton's espousal of the emission theory is said to have retarded scientific discovery. It might, however, be questioned whether, in the long-run, the errors of great men have not really the effect of rendering intellectual progress rhythmical, instead of permitting it to remain uniform, the retardation in each case being the prelude to a more impetuous advance. It is confusion and stagnation rather than error that we ought to avoid." Now, the underlying thought in the passage from the preface above quoted is manifestly the same as that here expressed. The object in both cases is, simply to bring out the uses of authority, and no candid reader will recognize any element of "self-laudation" in the one case any more than in the other.

It has hitherto been thought that, as discoveries are the result of mental operations, science is always the gainer, when an intelligent account is given of the intellectual processes by which a new result is reached; but it now seems that if one refers to his own thoughts he must expect to be snubbed as an egotist. And, particularly, if he attains conclusions of moment, involving the upsetting of former theories, and where it is of increased importance to know the mental operations that lead to them, he will be pretty certain to find some mocking cynic who will twit him with his "self-consciousness, explaining to itself and to others how it grew so great." It is a little comical, however, to take lessons in humility from a writer who mounts the judgment-seat and exhausts the vocabulary of abuse in depreciating others; or to listen to homilies on modesty from a journal that sets up each week to criticise all that is going on in the universe—while both are convicted of detraction on the basis of the most brazen perversions.

"THE CONFLICT OF AGES."

We ask careful attention to the argument of President White on the "Warfare of Science," the first installment of which opens the present number of the Monthly, and the second of which will appear in our next issue. The import of his clear-cut thesis, and the vigor, learning, and logical force, with which it is sustained, will command the admiration of all intelligent students of the subject. But that which makes President White's discussion unique, and especially valuable, at this time, is the copious notes and references by which it is enriched and fortified, and which open the way to the whole literature of the question for the benefit of those who desire to consult the original authorities. At this time, when the hot temper of controversy leads to much random and reckless statement, it is desirable to know, very clearly, what can be proved, and where the proof can be found: President White's article is, therefore, opportune, and will be especially valued at present, while it must also take its place as a permanent contribution to a question which is bound to be of increasing interest in the future.

That we may not be accused of partiality or injustice to opposite views, we print also, in this number, an elaborate and earnest argument, delivered at the inauguration of Vanderbilt University, by Dr. Deems, on the other side of the question. The address is liberal in spirit, and often bold in its concessions, but we can hardly assent to its opening declarations. The author

maintains that "the recent cry of 'the Conflict of Religion and Science' is fallacious and mischievous to the interests of science and religion, and would be most mournful if we did not believe that, in the very nature of things, it must be ephemeral. Its genesis is to be traced to the weak foolishness of some professors of religion, and to the weak wickedness of some professors of science."

On the contrary, we consider this conflict to be natural and inevitable, to be wholesome rather than mischievous; and having convulsed the world for centuries, and being still rife, with little prospect of speedy adjustment, we hardly see how it can be regarded as "ephemeral." Nor can it be much dependent upon the attributes here assigned to some of the controversialists. If the said professors of religion were brayed in a mortar until all their folly departed from them, and the said professors of science were all regenerated, the relations of the subjects would still give rise to hostility, and raise up new antagonists. No truce among the leaders can affect the deeper issues as viewed by the general mind. Something ought to be learned from experience, and that there has been a long and fierce antagonism between what has passed under the name of religion, and what has passed under the name of science, is sufficiently shown from the evidence furnished by President White. That the antagonism continues, is not because of the wrong-headedness of a few partisans who are bent upon stirring up strife, but because science is driving on with its researches, regardless of any thing but the new truth it aims to reach, while the religious world is full of anxiety and dread about what is going to happen as a consequence of this uncontrollable movement. Those who think the existing phase of the alleged conflict illusive are requested simply to consider the attitude of mind of the great mass of devout and sincerely religious people toward the more advanced scientific conclusions and scientific men of the present day. It is no test of the matter to determine how the great body of religious people now regard the science established in former times. The religious liberality of each age is put upon its trial by the questions arising in each age. In our own time biology is the branch of science that is most progressive and occupies the attention of, perhaps, the largest number of investigators who are busy inquiring about the origin of life, the antiquity of man, cerebral psychology, the laws of force manifested in living beings, and the evolution of organic forms in the course of Nature. How are such inquiries regarded by the multitude of devoutly religious people? Are they not considered "dangerous?" Are they not viewed by this class exactly as the new doctrines in astronomy and geology were viewed by the same class in former times, that is, as hostile to faith and subversive of religion? Is there no conflict here? Are the brand of "materialism" which is put upon biological study in our times, and the charge that a materialistic science is aiming to cut up religion by the roots, indicative of harmony between these parties? Science must go on, and, if her results thus far are bad, there is no prospect that they will be better in the future. There can be only one basis of substantial peace, and that is the entire indifference of religious people, *as such*, to the results of scientific inquiry. This they cannot attain until far better instructed than at present; and we apprehend that it will take very considerable time to reach that desirable consummation.

END OF THE PENIKESE SCHOOL.

THE proposition made three or four years ago, and due, as we understood, to Prof. Shaler, to establish a School of Natural History at Nantucket for the benefit of the teachers of the country,

and at the time of their vacation, we thought one of the most feasible and important educational movements of the time. The plan was comprehensive, involving the services of some twenty lecturers who were masters of the several departments of natural history; and it was received with such favor throughout the country, that it was certain a very large number of students would have collected there to avail themselves of the superior instruction that could have been afforded. The island, besides, was conveniently accessible, and the accommodations offered by the town ample, excellent, and moderate in price. There was, in short, large practical promise in the enterprise.

But it was not carried out, and in its stead there grew up another school in natural history, under the auspices of Messrs. Agassiz and Anderson, on another island, difficult of access and without accommodations. But few pupils could be taken, and the large expenses of the experiment, under the peculiar circumstances, had to be defrayed from without. The necessary funds not being forthcoming, the project collapsed, and the school is numbered among the things that were. Much regret has been expressed at the result; but we shed few tears over the failure of the Penikese School. Why should money be wasted in sustaining a school in an ill-chosen station that limits its usefulness and entails inordinate expense? We observe that the editor of *Nature*, in announcing the abandonment of the institution, and explaining the unpleasant controversy that accompanied it between Mr. Anderson, the donor of the island, and the trustees, speaks in a tone of strong regret at the result. He thinks it unfortunate that Mr. Anderson had not contributed a little more money, as, "had he done so, those interested in the success of the school would have had time to set about raising something like an endowment fund, and *a fine opportunity would have been afforded to the United States Government to show their appreciation of practical scientific teachers and scientific research.*" The italics here are our own, and the suggestion they convey admirably illustrates the easy tendency and universal readiness there is to go to Government for help to sustain every thing that cannot be sustained by the appreciation and liberality of the community. A school absurdly located, costly, and restricted, is not supported by the public—with all its appreciation of education and readiness to contribute to it whenever its contributions are wisely expended—and so the state is invoked to assume the burden due to bad calculations. We think it is a good deal better that the concern should have been wound up than to have dragged along in a precarious way, or got a subsidy from the Legislature, as it will perhaps cease to be a hindrance to the organization of other schools in better circumstances.

THE EDUCATION QUESTION AT MONTPELLIER.

THERE are many indications of a very serious struggle, almost coextensive with civilization, between ecclesiastical authority and the liberal spirit of the age on the subject of education. Religion may not be responsible for it, but religious bodies are involved in it, and it threatens to become a matter of increasing difficulty, notwithstanding our vaunted enlightenment and the success of free government. The most numerous sect of Christendom has its own policy on the subject of education, and clings to it invincibly, though with a wise discretion in the avowal of its claims. The passages given in the following letter are an undisguised statement of the demands of the Romish Church as to its right to educate mankind.

The following letter from Prof.

Tyndall, bearing upon this subject, lately appeared in the London *Times:*

"A learned French friend has favored me with a copy of a letter recently published in France, and bearing the following title: 'Letter of Monsignor the Bishop of Montpellier to the Deans and Professors of the Faculties at Montpellier.' Its date is the 8th of this month of December, 1875. One or two extracts from it may not be without their value for the people of England and of America, to whom, in our day, has fallen the problem of education in relation to the claims of Rome.

"The bishop writes to the deans and professors aforesaid:

"'Now, gentlemen, the holy Church holds herself to be invested with the absolute right to teach mankind; she holds herself to be the depositary of the truth—not a fragmentary truth, incomplete, a mixture of certainty and hesitation, but the total truth, complete, from a religious point of view. Much more, she is so sure of the infallibility conferred on her by her Divine Founder, as the magnificent dowry of their indissoluble alliance, that even in the natural order of things, scientific or philosophical, moral or political, she will not admit that a system can be adopted and sustained by Christians, if it contradict definite dogmas. She considers that the voluntary and obstinate denial of a single point of her doctrine involves the crime of heresy, and she holds that all formal heresy, if it be not courageously rejected prior to appearing before God, carries with it the certain loss of grace and of eternity.

"'As defined by Pope Leo X., at the Sixth Council of the Lateran, "Truth cannot contradict itself; consequently, every assertion contrary to a revealed verity of faith is necessarily and absolutely false." It follows from this, without entering into the examination of this or that question of physiology, but solely by the certitude of our dogmas, we are able to pronounce judgment on any hypothesis which is an anti-Christian engine of war rather than a serious conquest over the secrets and mysteries of nature.'

"Liberty is a fine word, tyranny a hateful one, and both have been eloquently employed of late in reference to the dealings of the secular arm with the pretensions of the Vatican. But 'liberty' has two mutually exclusive meanings—the liberty of Rome to teach mankind, and the liberty of the human race. Neither reconcilement nor compromise is possible here. One liberty or the other must go down. This, in our day, is the 'conflict' so impressively described by Draper, in which every thoughtful man must take a part. There is no dimness in the eyes of Rome as regards her own aims; she sees with a clearness unapproached by others that the school will be either her stay or her ruin. Hence the supreme effort she is now making to obtain the control of education; hence the assertion by the Bishop of Montpellier of her 'absolute right to teach mankind.' She has, moreover, already tasted the fruits of this control in Bavaria, where the very liberality of an enlightened king led to the fatal mistake of confiding the schools of the kingdom to the 'doctors of Rome.'

"Your obedient servant,

"JOHN TYNDALL.

"ATHENÆUM, *December* 16, 1875."

The University of Montpellier, to the deans and faculties of which the above notification is addressed, is one of the oldest and most honored universities of Europe. It was founded in the twelfth century, its medical faculty by the Spanish Arabs. Situated in what was formerly called Languedoc, one of the southern portions of France, it has a botanical garden, the first that was established in Christendom. Its Observatory has for ages been in repute, its Museums of Natural History and Fine Art have long been celebrated. It has made its city one of the intellectual centres of France.

In this university was first translated into Latin Ptolemy's great Greek work, the "Alma Gest." One of the regents was the first European to make tables of the moon, and to determine the obliquity of the ecliptic. He is honorably mentioned by Copernicus. In literature it is distinguished by being the seat of the earliest cultivation of a modern language. From the romance literature of Langue d'Oc, Petrarch and Dante took their inspirations.

But in another respect it has a memorable celebrity. Here the Inquisition was first organized, and Languedoc was the seat of the most dreadful persecutions that the world has ever witnessed. Thousands of persons were put to death, whole cities were burnt. The French Protestantism of the middle ages was extinguished by fire and sword. The professors and doctors of the university were expelled from the country.

Six centuries have not sufficed to abate this ecclesiastical bigotry. There is the Bishop of Montpellier claiming for his Church the exclusive right to teach mankind. He leaves no doubt as to what sort of teaching it would be. Nothing inconsistent with the dogmas of the Church. None of your astronomy, or geology, or physiology, or other atheistic sciences. Let American colleges and universities lay this thing to heart! Their turn may some day come.

LITERARY NOTICES.

THE NATURE OF LIGHT, WITH A GENERAL ACCOUNT OF PHYSICAL OPTICS. By Dr. EUGENE LOMMEL, Professor of Physics in the University of Erlangen. With 188 Illustrations. D. Appleton & Co. No. XIX. "International Scientific Series." Pp. 356.

A BOOK has long been wanted, making clear to the popular mind the most interesting and important principles of the beautiful science of optics. The subject is usually treated in a meagre way as a subdivision in our text-books of physics, and, even in the largest of these, the discussion of light is usually very incomplete. But no subject is more worthy of separate treatment, and Dr. Lommel has made a volume well worthy of its position in the "International Scientific Series." An interesting portion of one of his chapters, that dealing with the curious and wonderful phenomena of fluorescence, is given in our present number, furnishing a fair illustration of the clearness of the author's writing and the freshness of his presentation.

In an elaborate notice of the work, which appeared in *Nature*, it is remarked: "In the present treatise, Prof. Lommel has given an admirable outline of the nature of light and the laws of optics. Unlike most other writers on this subject, the author has, we think wisely, postponed all reference to theories of the nature of light, until the laws of reflection, refraction, and absorption, have been clearly set before the reader. Then, in the fifteenth chapter Prof. Lommel discusses Fresnel's famous interference experiment, and leads the reader to see that the undulatory theory is the only conclusion that can be satisfactorily arrived at. A clear exposition is now given of Huyghens's theory, after which follow several chapters on the diffraction and polarization of light-bearing waves. The reader is thus led onward much in the same way as the science itself has unfolded, and this, we think, is the surest and best way of teaching natural knowledge."

MIND: A Quarterly Review of Psychology and Philosophy. No. I., January, 1876. Pp. 156. Price $1.00, subscription $4.00 a year. Republished by D. Appleton & Co., New York.

WE have here the promise of a periodical new in its plan, broad and important in its scope, and very ably sustained. It represents the new departure in psychological study, from the point of view taken by Bain and the modern school; in fact, the project of its establishment is largely due to Prof. Bain himself, who will have an active share in its management, although the responsible editor is Prof. George Croom Robertson, of University College, London. The range and quality of this work will be best gathered from the following passages taken from the prospectus:

"MIND will be an organ for the publication of original researches, and a critical record of the progress made in Psychology and Philosophy.

"Psychology, while drawing its fundamental data from subjective consciousness, will be understood in the widest sense, as covering all related lines of objective inquiry. Due prominence will be given to the physiological investigation of Nerve-structures. At the same time, Language and all other natural expressions or products of mind, Insanity and all other abnormal mental phases, the Manners and Customs of Races as evincing their mental nature, mind as exhibited in Animals generally—much of what is meant by Anthropology, and all that is meant by Comparative Psychology—will come within the scope of the Review.

"The practical application of psychological theory to Education will receive the attention it so urgently claims at the present time.

"Beyond Psychology, account will be taken of Logic, Æsthetics, and Ethics, the theory of mental functions being naturally followed by the doctrine of their regulation.

"For the rest, MIND will be occupied with general Philosophy. Even as a scientific journal, it cannot evade ultimate questions of the philosophical order, suggested as these are with

peculiar directness by psychological inquiry. There is, also, a function truly philosophical which only the investigator of mind is in a position to discharge, the task, namely, of collating and sifting the results of the special sciences with a view alike to insight and conduct. But MIND will, further, expressly seek to foster thought of bold sweep—sweep that can never be too bold, so be that it starts from a well-ascertained ground of experience, and looks to come again there to rest."

The first number well justifies the promises here made, and there is every reason to believe that the succeeding issues will do so in a still greater degree.

REPORT OF THE FORTY-FOURTH MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: held at Belfast, in August, 1874. London: John Murray, 1875.

ONE of the most valuable features of the yearly volumes of the British Association is the publication of extended "Reports on Researches in Science," which are annually made on special subjects by small committees of eminent men who are themselves working in those subjects. Thus, in the volume before us, there are no less than *thirty* such reports, occupying about 360 octavo pages. The Association often aids in an investigation by the appropriation of a small sum of money, and in return it receives a report on the progress of the work, besides the gratification of having assisted some research that otherwise might have been long delayed.

For instance, since 1848 reports have been given upon the observations of Luminous Meteors, which contain nearly all the known facts relating to meteorites, arranged in an orderly form, and in some degree sifted. This report for 1873–'74 contains 90 pages.

Reports on Earthquake Phenomena, on Tides, on the Waves of the Atmosphere, on Magnetic and Meteorological Observations, and many other similar subjects, are to be found in the pages of the past volumes, and often the facts of such reports are collected nowhere else. From the present volume we extract almost at random the titles of a few of these reports, which may serve to show the nature of the subjects which are yearly brought to the attention of the meetings: "Report on the Recent Progress and Present State of Systematic Botany" (27 pages); "On the Rainfall of the British Isles for 1873–'74" (43 pages); "On the Treatment and Utilization of Sewage" (14 pages); "On Cyclone and Rainfall Periodicities in Connection with Sun-spots" (23 pages); "On the Erratic Blocks of England and Wales" (8 pages); "On Instruments for measuring the Speed of Ships" (9 pages), etc. The committees making these reports counted among their members the most eminent men of England—Lyell, Lubbock, Boyd-Dawkins, Bentham, W. K. Clifford, Balfour Stewart, Clerk-Maxwell, Huxley, Galton, Sir William Thomson, Huggins, Lockyer, De la Rue, and many others scarcely less known. With such subjects reported on by so eminent specialists, it is easy to see how these reports have come to have so high a value.

The Belfast meeting was attended by nearly 2,000 members, and over £2,000 was received from fees, etc.; £1,080 was appropriated for scientific purposes; £400 for various works of the section of mathematics and physics (printing mathematical tables, rainfall and meteor reports, thermo-electricity, etc.); £155 for researches in chemistry; £280 for various geological explorations; £170 for biology; £100 for the Palestine Exploration Fund; £25 for statistics (economic effect of combinations of laborers or capitalists); and £50 for instruments for measuring the speed of ships. This abstract will give some idea of the practical benefit to science which the Association gives, and it is also instructive as showing for what purposes its money is spent.

The last 232 pages of the volume are devoted to an abstract of the proceedings of the sections. We find that the section of mathematics and physics occupies 44 pages, the chemical section has 22 pages, geological 29 pages, biological 64 pages, geographical 24 pages, statistical 27 pages, and finally that the mechanical section occupies 20 pages. In a rough way this shows the amount of attention paid to the various branches at the 1874 meeting, and it is accurate enough to indicate the great amount of work now doing in biology in England, which is a noteworthy feature of this and preceding reports.

STRENGTH OF BEAMS UNDER TRANSVERSE LOADS. By W. ALLAN. Pp. 114. Also SEWERAGE AND SEWAGE UTILIZATION. By W. C. CORFIELD, M. A. New York: Van Nostrand. Pp. 128. Price, 50 cents each.

IN the first of these two little volumes the practical builder will find a discussion of the most important and common cases of horizontal beams under vertical loads. The problems are worked out without having recourse to the higher mathematics. The second volume contains, in abridged form, a series of lectures delivered by Prof. Corfield before the School of Military Engineering at Chatham, England. The question of sewerage and sewage utilization is one of the urgent problems of modern life, and it yet awaits satisfactory solution. Meanwhile, Mr. Van Nostrand does the public a service by placing within the reach of all the views of so eminent an engineer as Prof. Corfield upon these subjects.

NOTES OF THE MANUFACTURE OF POTTERY AMONG SAVAGE RACES. By CH. FRED. HARTT, A. M. Pp. 70. Rio de Janeiro: *South American Mail* print.

PROF. HARTT here, in the first place, briefly considers the question of the origin of the ceramic art. When, where, how did it originate? No positive answer can be given to these questions. Like other human arts, it is the result of a long evolution, and its simple beginnings we may never be able to find out. So much, however, is certain, namely, that the finest porcelain wares are the true lineal descendants from the pottery of the savage. The author next considers the materials employed and the methods followed in the building of a vessel. Before the advent of Europeans, pottery in America was made by hand, the potter's wheel being unknown. He finds the method of fashioning vessels out of coils of clay widely practised in South America. The manufacture is everywhere exclusively in the hands of the women.

THE DIFFERENCE OF THERMAL ENERGY TRANSMITTED TO THE EARTH BY RADIATION FROM DIFFERENT PARTS OF THE SOLAR SURFACE. Pp. 10.

THIS is a reprint of a communication in *Nature* by Mr. John Ericsson, in which he points out defects in Father Secchi's method of measuring the intensity of the sun's radiant heat. Secchi's method is that of projecting the sun's image on a screen, and then measuring the temperature at different points by means of thermopiles. Ericsson adopts the method of *direct* observation, and employs a special apparatus devised by himself. Mr. Ericsson estimates the absorption by the solar atmosphere at not over 0.144 of the radiant heat emanating from the photosphere. The intensity of radiation from the border of the sun he estimates at 0.638 of the intensity of radiation from an equal area of the central region.

CHECK-LIST OF NOCTUIDÆ OF AMERICA, NORTH OF MEXICO. By A. R. GROTE, A. M. Pp. 28, with Plate. Price, $1. Buffalo, N. Y.: Reinecke & Zesch.

OF the twelve hundred North American species of *Noctuæ*, less than thirty, we are informed by Mr. Grote, are considered identical with European forms. The facts seem to point to a common origin of many of the forms, and it is the author's opinion that the European and North American *Noctuæ* are in part descended from species living over a common territory, and that the Glacial epoch separated the stocks. The list of species here given includes a complete synonymy of the *Noctuidæ* of America north of Mexico, so far as known. It is invaluable to the student of entomology.

STATE MEDICINE IN ITS RELATIONS TO INSANITY. By Dr. NATHAN ALLEN. Pp. 31.

DR. ALLEN considers the subject of insanity in the six New England States. He finds that in Massachusetts, from 1850 to 1870, the increase of insanity was 12 per cent. greater than the increase of population, and the same is to be said of the other New England States. He favors consigning the chronic insane to *homes*, instead of keeping them in hospitals. What they need is, not medical treatment, but suitable exercise, sunlight, air, proper nourishment, etc. He also advocates the adoption by the State of measures for the *prevention* of insanity. The dissemination of more correct views of the true way of living and a more rigid observance of the laws of health and Nature would, no doubt, greatly diminish the frequency of mental disease.

THE NEW METHOD OF GRAPHICAL STATICS. By A. J. DU BOIS, C. E., Ph. D. 60 Illustrations. Pp. 80. Price, $2. New York: Van Nostrand.

THIS book is made up of a series of articles which appeared originally in Van Nostrand's *Engineering Magazine*. The author's object is to win more general attention to a new method for a graphical solution of statical problems, which, during the last ten years, has been gradually developed and perfected, and which offers to the architect, civil engineer, and constructor, a simple, swift, and accurate means for the solution of a great number of practical questions.

REPORT UPON THE CONDITION OF AFFAIRS IN ALASKA. By H. W. ELLIOTT. Washington: Government Printing-Office. Pp. 277.

IN 1874 Mr. Elliott was directed by the Treasury Department to visit Alaska, for the purpose of studying and reporting upon the present condition of the seal-fisheries; the haunts and habits of the seal; the preservation and extension of the fisheries; the statistics of the fur-trade; and the condition of the natives. The results are contained in the volume before us. The work is full of valuable information. It is divided into nine chapters, treating of the "Character of the Country;" "Condition of the Natives;" "Duty of the United States Government;" "Trade and Traders;" "The Sea-Otter;" "The Seal-Islands;" "Habits of the Fur-Seal;" "The Sea-Lion;" "Fish and Fisheries;" and the "Ornithology of the Prybilov Islands."

OUR WASTED RESOURCES. By WILLIAM HARGREAVES, M. D. New York: National Temperance Society. Pp. 201. Price, $1.25.

DR. HARGREAVES quotes statistics to show that, in 1873, the income of the people of the United States exceeded $7,000,000,000. He thinks that, to the use of intoxicating drinks, nearly all of the crime and pauperism of the country is to be attributed. He compares the cost of intoxicating liquors with the total receipts of sundry industries; sums up the losses of the country from the trade in liquors; tries to show that the use of liquors and the liquor-trade destroy the influence of education. Finally, he lays down the proposition that "the use of and the traffic in strong drinks impede the progress of the Christian Church, and the spread of the gospel."

NOTES OF TRAVEL IN AFRICA. By C. J. ANDERSSON. New York: Putnam's Sons. Pp. 318. Price, $2.00.

THERE appears to exist in the public mind a genuine interest in the exploration of Africa, and the number of books of African travel published within the last ten years is enormous. The writings of C. J. Andersson have in no small measure contributed to the awakening of this curiosity, and doubtless the present work, made up from the memoranda of that distinguished traveler, will be read with the same eagerness as his earlier publications.

DISSERTATIONS AND DISCUSSIONS. By J. STUART MILL. New York: Holt & Co. Pp. 294. Price, $2.50.

THIS is the fifth volume of the "Dissertations and Discussions," and it completes the series. It contains five papers on "Land Tenure;" also essays on "Endowments;" on "Labor;" on "Treaty Obligations;" on Maine's "Village Communities;" Taine's "Intelligence;" Grote's "Aristotle;" Baer's "L'Avere e l'Imposta;" and Leslie's "Land Question."

A PRACTICAL TREATISE ON SOLUBLE GLASS. By Dr. LEWIS FEUCHTWANGER. Pp. 164. New York: L. Feuchtwanger & Co.

THE author points out the manifold uses of soluble glass, for instance, as a means of preserving timber and making it non-inflammable; as an ingredient in the composition of artificial stone; for mixing with paints to be applied to the surface of metals, glass, and porcelain; in soap-making; in calico-printing, etc.

REPORT OF THE COMMISSIONER OF EDUCATION FOR 1874. Pp. 935.

CONTAINS, in addition to the observations and suggestions of the commissioner, a great mass of statistics relating to the state of education throughout the country in the year 1874.

DR. DRAPER'S "CONFLICT."—There have been published of Dr. Draper's book, "The Conflict," eight editions in America, and five in London. It has been translated into French, and is in its third edition in Paris. The German translation made by Dr. Rosenthal has had a similar success. A Polish translation has been made in the University of Warsaw; a Servian one by Prof. Meta Rakitch, in Belgrade. The Spanish translation is by Señor Arcemis, the astronomer of Cadiz. The Russian is under examination by the censorship.

PUBLICATIONS RECEIVED.

Exploration of the Colorado River of the West. By Major J. W. Powell. Washington: Government Printing-Office. Pp. 291, with Maps.

Science By-ways. By R. A. Proctor. Philadelphia: Lippincott. Pp. 422. Price, $4.00.

Selection and Use of the Microscope. By J. Phin. New York: Industrial Publication Co. Pp. 131. Price, 75 cents.

Report on the Wisconsin Institution for the Blind, 1875. Madison, Wis.: E. B. Bolens. Pp. 20.

Bulletin of the United States National Museum, No. 2. Washington: Government Printing-Office. Pp. 50.

American Journal of Microscopy. Monthly. New York: Industrial Publication Co. 50 cents per year.

Forms of Life found in the Oral Cavity. By C. N. Peirce, D. D. S. Lancaster, Pa.

Pennsylvania Journal of Dental Science. Pp. 23.

Bridge and Tunnel Centres. By J. B. McMaster. New York: Van Nostrand. Pp. 106. Price, 50 cents.

Scientific Monthly. E. H. Fitch, Editor and Publisher. Toledo, O.: Pp. 96. Price, $3.00 per annum.

Geological Notes. By W. B. Rogers. Pp. 13.

Circulars of the Bureau of Education. Washington: Government Printing-Office. Pp. 130.

Vick's Floral Guide for 1876. Rochester, New York: Vick & Co. Quarterly, 25 cents per year.

Geological Survey of Minnesota, 1874. By N. H. Winchell. St. Paul: *Pioneer Press* print. Pp. 36, with Maps.

Transactions of the American Society of Civil Engineers, 1875. Pp. 49.

Safety-Valves. By R. H. Buell. New York: Van Nostrand. Pp. 100. Price, 50 cents.

Mammoth Cave of Kentucky. By W. S. Forwood, M. D. Philadelphia: Lippincott. Pp. 241, with Illustrations.

Three Months in Old Hospitals of Paris. By R. Ludlam, M. D. Philadelphia: Sherman & Co. Pp. 16.

Report of the United States Treasurer, 1875. Washington: Government Printing-Office. Pp. 67.

Post-Nasal Catarrh. By B. Robinson, M. D. New York: Trow & Son. Pp. 29.

Does Matter do it all? By Epes Sargent. Boston: Colby & Rich. Pp. 16.

Zappus Hudsonius, and Lagopus Leucurus. By E. Coues. Washington: Government Printing-Office. Pp. 10.

Necessity of a Mechanical Laboratory. By R. H. Thurston. Philadelphia: W. P. Kildare, Printer. Pp. 10.

MISCELLANY.

Relations of Chemistry to Pharmacy and Therapeutics.—We present herewith the main points of an instructive address delivered by Dr. T. Sterry Hunt before the Massachusetts College of Pharmacy, on "The Relations of Chemistry to Pharmacy and Therapeutics."

With the eighteenth century is connected the birth of modern chemistry; and, while Priestley and Lavoisier are honored as having given a new impulsion to chemical theory, the Swedish apothecary Scheele will always be remembered as one who probably enriched the science with more discoveries than either of them. The three brightest names on the roll of great chemists in our century have been gathered from

the ranks of the pharmaceutical profession, viz., Davy, Liebig, and Dumas. But the debt owed by chemistry to pharmacy has been amply repaid: the labors of the chemist have transformed the pharmaceutical art, replacing empiricism by science, enriching the materia medica with a vast number of new substances, and introducing new processes. Such old-fashioned drugs as coral, egg-shells, and the like, were shown by the chemist to possess no other value than belongs to the calcareous salts of which they are chiefly composed. Iodine was shown to be the active principle in the drug, calcined sponge; and henceforth iodine takes the place of the crude and bulky residue from the burning of sponge. In like manner quinine and morphine replaced cinchona-bark and opium.

In cases where the medicinal virtues are not apparently lodged in a single principle capable of being isolated, pharmacy has recourse to other processes, and obtains by expression, percolation, and evaporation, or distillation, often *in vacuo*, concentrated extracts which enable us to dispense with the crude drugs. Thus, for a rough example, by means of the sulphide of carbon the subtile perfumes of the violet and jasmine have been isolated. The artificial formation of urea and valerianic and benzoic acids opened up a new field for chemistry and pharmacy. By a careful dissection, as it were, of certain organic principles, we have learned to reconstruct them; and the triumphs of this method are seen in the artificial production of indigo, orcine and alizarine, and the odorant principle of vanilla. What wonder, then, that the chemist should now aspire to produce, artificially, the active principles of the poppy and cinchona, and render cheaper those precious drugs, morphine and quinine? These problems are destined to be solved at no distant day.

The history of anæsthetics is next traced by the author from the discovery of the physiological action of nitrous oxide by Davy to that of chloral by Liebreich. From this he passes to the subject of the chemical changes undergone by drugs in the animal economy, and the relations of these changes to physiological action. The mineral salts of many of the metals, such as sulphates and chlorides, act, to a great extent, like foreign substances when taken into the stomach, forming insoluble compounds with albuminous matters; but, when combined with certain organic acids, these metals are in a condition favorable to absorption. Thus, it is that the citrates, tartrates, and lactates of bismuth, antimony, iron, etc., are now advantageously employed in medical practice.

It having occurred to a chemist that salicylic acid might be antiseptic like carbolic acid, he made experiments which resulted in showing that in this almost tasteless body we possess an antiseptic agent of great power.

The immense advance made in the pharmaceutical art and the constant contributions brought to it by chemistry demand each year a higher education for the profession of pharmacy, and the day cannot be far distant when the need of a regular training and a thorough scientific education will be held to be as indispensable for the pharmacist as for the physician and the surgeon.

Haeckel on Scientific Institutions.—In his latest book ("Ziele und Wege der heutigen Entwickelungsgeschichte") Prof. Haeckel, the great apostle of Evolution in Germany, announces the discovery of the following law: "In all the magnificent scientific institutes founded in America by Agassiz, the following empirical law, long recognized in Europe, has been confirmed, viz.: that the scientific work of these institutes and the intrinsic value of their publications stand in an inverse ratio to the magnitude of the buildings and the splendid appearance of their volumes. . . . I need only refer," he adds, "to the small and miserable institutes and the meagre resources with which Baer in Königsberg, Schleiden in Jena, Johannes Müller in Berlin, Liebig in Giessen, Virchow in Würzburg, Gegenbaur in Jena, have not only each advanced his special science most extensively, but have actually created new spheres for them. Compare with these the colossal expenditure and the luxurious apparatus in the grand institutes of Cambridge, Leipsic, and other so-called great universities. What have they produced in proportion to their means?"—*Pall Mall Gazette.*

Maturity of Timber-Trees.—A paper in the "Transactions of the Scottish Arboricultural Society" contains the following information with regard to the time required for various kinds of timber-trees to reach maturity: "The oak can never be cut down so profitably when small as when well matured, and having plenty of heart-wood. The timber is seldom of much value until it has reached the age of 100 years. Ash can be cut down more profitably in its young state than other hard-wood trees. When clean grown, and from thirty to forty years of age, it is in great demand for handle-wood and for agricultural implements. Beech is of very little value in its young state, and is seldom cut till well grown. Birch can be cut down profitably at about forty years old. Horse-chestnut, when grown on good soil, and in a sheltered position, can be profitably cut down when it attains large dimensions. Elms (Scotch and English) should never be cut until they are from eighty to one hundred years old. Poplars can generally be profitably sold when about fifty years old. Sycamore, growing in good soil, may be profitably cut down when about one hundred years old."

Source of the Nitrogen used by Plants.—The average life of an apple-tree in Normandy is estimated by M. Isidore Pierre at fifty years, and its nitrogen product (in leaves, fruit, wood, and roots) at 26 kilogrammes (about 60 pounds). This amount of nitrogen corresponds to 5,200 kilogrammes of farm manure, or 100 kilogrammes per year. But the tree is far from receiving any such amount; according to the author, the most liberal cultivator does not supply more nitrogen than is found in the seeds. The question then arises, Whence comes the remainder of this nitrogen? M. Thenard, in a communication to the Paris Academy of Sciences, denies that it comes directly from the soil, or from the manure, and holds that it is derived from the air *through* the soil. In confirmation of this, he cites the grape-vines of Clos-Vougeot, the youngest of which were planted in 1234, and which annually receive only one kilogramme of manure. The amount of nitrogen contained in this quantity of manure is inconsiderable, as compared with what is contained in the grapes, the leaves, and the wood.

Cranial Measurements.—Two noteworthy results of the comparative measurements of the crania belonging to historic and prehistoric times were dwelt upon by Prof. Rolleston, in his presidential address to the Section of Anthropology, at the last meeting of the British Association. It might be assumed that skulls from the earliest sepulchres would present the smallest capacity, and that the size of the brain-case has since increased with the intellectual development of our race. But this assumption is curiously contradicted by the facts. Indeed, the cubic contents of many skulls from the oldest known interments considerably exceed the capacity of modern European skulls of average build. Surprise at such a result may, however, be tempered by the reflection that the skulls which we have obtained from the earliest tumuli are probably those of the chiefs of their tribes, who may have been selected by virtue of their great energy. Nor should it be forgotten that in savage communities the chiefs come in for a larger share of food, and are, consequently, men of well-developed frames, and of more portly presence than their fellows. As to the poorer specimens of humanity in those days we probably know nothing, as they were denied burial in the tumuli, and have left their remains we know not where. Another curious fact is, that the female skulls from the earliest sepultures do not differ in capacity from the contemporary male skulls to the same degree as the crania of the two sexes differ at the present day. But it must be borne in mind that in those early times there was a greater struggle for existence, and that the division of labor was not carried out to a large extent, so that the tendency to a differentiation of the crania was less marked than in modern times.

An Indian Mill.—On the farm of Mr. Hollis Smith, near Marengo, Calhoun County, Michigan, there exists an interesting monument of aboriginal life, known in the locality as "The Indian Mill." As described in a letter to us by Mr. W. H. Payne, of

Adrian, it consists of a great block of free-stone, about fifteen feet in length and five feet in width. Near one edge of this block there is a hole fifteen inches deep, having a diameter at the top of twenty inches, resembling a large mortar. "At the time of my visit," writes Mr. Payne, "this 'mill' was filled with water from recent rains. This was measured as it was dipped out, and amounted to fourteen gallons. Early settlers report that this spot was frequented by Indians, who brought thither their corn to be ground or pounded in this stone mortar. In the vicinity are seen many broad, smooth-faced stones, whose surfaces seem to have been highly heated. It is not improbable that these were used by Indians whereon to bake their cakes of corn. The grain was pounded as follows: A spring-pole was attached to one of the trees which stood near, and from the free end of this was suspended over the mortar, by means of twisted bark, a stone of convenient form and size. Stones suitable for this purpose lie beside the 'mill,' and it is probable that they once served the purpose above indicated."

Excommunicated Insects.—*À propos* of the efforts in progress to destroy the phylloxera and other insect scourges in France, a writer in *La Nature* gives a curious bit of information relative to the way in which such pests used to be proceeded against when science, save so far as it could be made to agree with Romish dogmas, had no existence for the world. In 1120, the Bishop of Laon formally excommunicated all the caterpillars and field-mice. In 1488, the grand-vicars of Autun commanded the parish priests of the vicinity to enjoin the weevils to cease their ravages, and to excommunicate them. In 1535, the grand-vicar of Valence cited the caterpillars to appear before him for trial. He kindly assigned them counsel for their defense, and, as they did not appear, proceeded against and sentenced them, *in contumaciam*, to clear out of his diocese—a command which they probably obeyed!

During the seventeenth century, thirty-seven similar judgments, against both insects and quadrupeds, were issued. One is on record, during the eighteenth century, fulminated against a cow; and there is still another, of later date, due to a judge of Falaise, who condemned and hanged a sow for killing a child.—*Christian Intelligencer.*

Putting out Fires at Sea.—Liquid carbonic acid is proposed by Lieutenant F. M. Barber, U. S. Navy, as an agent for extinguishing fires on board ship. His plan, as communicated to the *American Chemist*, is to have, in some suitable place in the ship, a flask or flasks about three feet in length, and one foot in diameter, containing about 100 pounds of the gas in the liquid state. From the top of the flask, a small iron pipe is to be permanently fitted along the waterways throughout the entire length of the ship. From this main pipe branch pipes pass to every storeroom and compartment, each branch to be controlled separately by means of a cock. On the alarm of fire, the hatches are to be battened down, the cock in the branch pipe leading to the compartment where the fire is discovered is to be opened, and also the cock in the main next the gas-flask. The liquid gas passes out through the pipe in the form of vapor as soon as the pressure is removed, and is driven to the apartment where the fire is. This compartment it fills from the bottom up, without being diluted with the air. Given the cubic contents of any compartment, and the cubic space occupied by the cargo in it, sufficient gas can be admitted so as to render it absolutely certain that no fire can exist there. By then shutting the cock in the main pipe, the remainder of the gas is kept from vaporizing until such time as it may be required. This method of extinguishing fires is absolutely effectual; furthermore, it is simple, and involves no great expense. The only difficulties which seem to stand in the way of its practical application, are—1. The want of an apparatus for the expeditious and economical production of the liquid gas; and, 2. The want of suitable vessels to hold it at all temperatures. These difficulties, however, have been removed, and hence there exists no reason why all ships should not be provided with this effectual means of preventing disaster by fire.

In England, an apparatus for extin-

guishing fires on shipboard was recently patented. This apparatus, the "pyroletor," as it is called, consists of a small double pump worked by hand, which sucks up through a tube on each side of it strong muriatic acid, and a solution of bicarbonate of soda; these commingle in a generator forming part of the pump, and the carbonic-acid gas and bicarbonate solution pass at once down a metal pipe to the hold, along whose keelson runs a perforated wooden box which admits of the gas passing through to the burning material. The agent, therefore, for the extinction of fire, is dry carbonic-acid gas, which has no action on the cargo. The *Chemical News* describes as follows an exhibition lately given of the working of the "pyroletor:" "The entire hold of a large wooden barge was covered to a depth of several feet with wood-shavings and cotton-waste saturated with turpentine and naphtha. A temporarily-raised and by no means air-tight wooden deck, with loosely-fitting boards, formed the wide hatchway-covering. The combustible material having been set on fire, the flames immediately ran along the entire cargo and issued above the temporary deck, which was then covered with boarding. The 'pyroletor' having been brought into action, the fire was completely extinguished in four minutes, though nearly half a gale was blowing." It is computed that a 1,200 ton ship requires half a ton of each of the chemicals, costing about $100.

Physical Characters of the British.—Dr. Beddoe, at the recent meeting of the British Association, advocated the necessity, from a practical point of view, not from that of mere scientific curiosity, of obtaining more extensive and accurate information as to the physical characters of man in Britain than could be obtained by private investigations. He desired to inquire thoroughly and systematically into the rates of growth, average stature, weight, etc., of men and women under normal or abnormal conditions, so as to have a fair starting-point for further investigation and action. Lord Aberdare said that some time since it was ascertained that the Irishman was superior to the Scotchman in vigor, and that the Englishman was lowest of the three. This he attributed to the fact that in Ireland and Scotland children were fed on food appropriate to them. He moved that a committee be appointed to collect observations on the subject of the heights and weight of human beings in Great Britain and Ireland, and that a grant of money be made to defray the expenses of such an inquiry. This resolution was adopted.

Native Home of the Rocky Mountain Locust.—In view of the great interest and alarm excited by the ravages of the grasshoppers in the West last year, Prof. C. V. Riley, State Entomologist of Missouri, gives, in the last seventy-five pages of his Seventh Annual Report, a very full and interesting account of the natural history of this insect, including the plants it feeds on, the parasites that feed on it, and a history of its noted incursions, with the means that may profitably be employed to arrest its depredations. From the section on its "native home" we quote some interesting remarks concerning the *spread* of the insect.

Having in July, 1874, given the opinion that the swarms of that year would reach the western counties of Missouri too late to do serious damage, and that they would not extend eastward beyond a line drawn, at a rough estimate, along longitude 17° west from Washington—an opinion, by-the-way, that was remarkably confirmed by subsequent events—the professor here proceeds to give his reasons for that conclusion:

'But it will be asked, 'Upon what do you base this conclusion, and what security have we that at some future time the country east of the line you have indicated may not be ravaged by these plagues from the mountains?' I answer that, during the whole history of the species, as I have attempted to trace it in the chronological account already given, the insect never has done any damage east of the line indicated, and there is no reason to suppose that it ever will do so for the future. . . .

"'But why,' it will again be asked, 'will not the young from the eggs laid along the eastern limit you have indicated hatch and spread farther to the eastward?' Here, again, historical record serves us, and there are, in addition, certain physical facts which help to answer the question.

"There is some difference of opinion as to the precise natural habitat and breeding-place of these insects, but the facts all indicate that it is by nature a denizen of great altitudes, breeding in the valleys, parks, and plateaus of the Rocky Mountain region of Colorado, and espe-

cially of Montana, Wyoming, and British America. Prof. Cyrus Thomas, who has had an excellent opportunity of studying it—through his connection with Hayden's geological survey of the Territories—reports it as occurring from Texas to British America, and from the Mississippi (more correctly speaking, the line I have indicated) westward to the Sierra Nevada range. But in all this vast extent of country, and especially in the more southern latitudes, there is every reason to believe that it breeds only on the higher mountain elevations, where the atmosphere is very dry and attenuated, and the soil seldom, if ever, gets soaked with moisture. . . .

"My own belief is, that the insect is at home in the greater altitudes of Utah, Idaho, Colorado, Wyoming, Montana, Northwest Dakota, and British America. It breeds in all this region, but particularly on the vast hot and dry plains and plateaus of the last-named Territories, and on the plains west of the mountains; its range being bounded, perhaps, on the east by that of the buffalo-grass.

"In all this immense stretch of country, as is well known, there are vast tracts of barren, almost desert land, while other tracts, for hundreds of miles, bear only a scanty vegetation, the short buffalo-grass of the more fertile prairies giving way, now to a more luxurious vegetation along the water-courses, now to the sage-bush and a few cacti. Another physical peculiarity is found in the fact that while the spring on these immense plains often opens as early, even away up into British America, as it does with us in the latitude of St. Louis, yet the vegetation is often dried and actually burned out before the first of July, so that not a green thing is to be found. Our Rocky Mountain locust, therefore, hatching out in untold myriads in the hot sandy plains, five or six thousand feet above the sea-level, will often perish in immense numbers if the scant vegetation of its native home dries up before it acquires wings; but if the season is propitious, and the insect becomes fledged before its food-supply is exhausted, the newly-acquired wings prove its salvation. . . . Prompted by that most exigent law of hunger—spurred on for very life—it rises in immense clouds in the air to seek for fresh pastures where it may stay its ravenous appetite. Borne along by the prevailing winds that sweep over these immense treeless plains from the northwest, often at the rate of fifty or sixty miles an hour, the darkening locust-clouds are soon carried into the more moist and fertile country to the southeast, where, with sharpened appetites, they fall upon the crops like a plague and a blight. . . . The hotter and drier the season, and the greater the extent of the drought, the earlier will they be prompted to migrate, and the farther will they push on to the east and south.

"The comparatively sudden change from the attenuated and dry atmosphere of five to eight thousand feet or more above the sea-level to the more humid and dense atmosphere of one thousand feet above that level, does not agree with them. The first generation hatched in this low country is unhealthy, and the few that attain maturity do not breed, but become intestate and 'go to the dogs.' At least, such is the case in our own State, and in the whole of the Mississippi Valley proper. . . ."

Temperature and Vegetation in Different Latitudes.—A communication on this subject was made by M. Alphonse de Candolle to the Academy of Sciences of Paris, and reported in the *Comptes Rendus* for June 7th. The object of the inquiry was to test the accuracy of the very common observation that vegetation comes forward much more rapidly in spring in northern latitudes than in the warmer regions of the temperate zone. Experimenting with seeds of several species of plants sent to him from Northern and Southern Europe, he found that those from the north were most precocious. Twigs, obtained in the winter, of the white poplar, tulip-tree, catalpa, and the *Carpinus betulus*, from Montpellier, were there tried with twigs from the same species at Geneva. They were laid aside, so that their temperature might become alike, and were then placed in water, a little sand being put in the bottom of the jar.

The German, or more northern branches, leafed out first; the difference of time between the leafing of the respective pairs being from eighteen to twenty-three days.

It is an interesting question, "Why do northern plants develop more rapidly than southern ones?" Prof. de Candolle comments on it in this wise: "The buds of a tree are in a continual struggle. The later, like badly-placed ones, develop imperfect branches which are oftener stifled. The most precocious prevail, unless indeed they suffer from frost. In this way comes a selection, and a successive adaptation of the tree to the climate."

Buds, by this means, acquire peculiarities which are persistent. If there be promptness and quickness of growth, these qualities are continually reproduced. An instance of the persistency of acquired peculiarities is given in a horse-chestnut tree near Geneva, which, on a single branch, produced double flowers about the year 1822, and has continued to do so; and all the doubled-flowered horse-chestnuts in the

world are thought to be derived from that stock.

De Candolle, however, speaks of the more profound hibernal repose of northern plants producing in the buds greater susceptibility to the heat of spring. But, Prof. Gray, commenting on this in the *American Journal of Science* for September, suggestively remarks that "the way in which this increased susceptibility arises is not stated," and adds, "that natural selection would operate upon trees as upon cereal grains, inducing precocious races better adapted to the short summers, only more time would be required in case of the tree."

Influence of Water on Climate.—At the late meeting of the British Association, Prof. Hennessy read a paper on the "Influence of the Physical Properties of Water on Climate." The object of the paper was to contradict the opinion formerly expressed by Sir J. Herschel, that "water does not distribute heat in any thing like the same degree as land." According to Prof. Hennessy, of all substances largely existing in Nature, water is the most favorable to the absorption and distribution of solar heat. A sandy soil, such as that of the Sahara, although capable of exhibiting a very high temperature during the day, becomes cool during the night, and is one of the worst media for storing up the heat derived from sunshine. Water, on the contrary, stores up heat better than almost any other body. An objection was offered by Prof. Everett, based on the generally-accepted fact that the temperature of the Southern Hemisphere is lower than that of the northern, despite the greater predominance of water in the former. This Prof. Hennessy denied to be a fact.

Curious Behavior of a Snake.—For the following account of an interesting exhibition of serpent-cunning, we are indebted to Mr. E. Lewis, of Brooklyn: "On the 20th of June last, while visiting at the house of a relative on Long Island, I saw on his lawn an adder, a species of snake common in that region. It seemed gentle, and, when approached, made no effort to escape. Wishing to observe its motions, I touched it with a stick, when, instead of moving away, it commenced a series of contortions that greatly surprised me. Nothing that I had seen in the motion of serpents of any kind showed so clearly as did this instance the extraordinary flexibility of their vertebral column. The contortions ended by the creature thrusting its head and open mouth into the loose dirt on the surface as if in great distress, when, partially extending itself and turning on its back, it lay as if quite dead. I lifted it on the stick, and carried it some yards, and laid it on the grass, but observed, in laying it down, that it showed some rigidity, in its tendency to turn or lie on its back. Others, who had witnessed the action of the snake, now left, and I stepped behind a tree for further observation.

"In two or three minutes the head of the snake rose a little, and I could see that it was observing the situation. Presently it turned on its belly, and was in a position to move away; but, on being touched, it turned on its back again. Finally, it raised its head, turned over, and, seeing no one, crawled slowly away.

"This behavior in the snake was new to me, and has not been observed by any with whom I have conversed concerning it. It seems to me probable that it arose from the instinct of self-preservation, or from the equally strong instinct for preservation of its young. No young ones were seen, however, but they may have been near in the grass, and it was a season of the year when their presence might be expected. There was certainly nothing more curious or strange in the snake's feigning death than in birds feigning lameness, and other animals feigning death, when themselves or their young are in danger; but I conclude the phenomenon is unusual with serpents."

A New Enemy of Submarine Cables.—In 1865 the world-renowned special correspondent of the London *Times*, W. H. Russell, modestly gave utterance to a prophecy which time has since fulfilled almost to the letter. He then wrote: "As a mite would in all probability never have been seen but for the invention of cheese, so it may be that there is some undeveloped creation waiting *perdu* for the first piece of

gutta-percha, which comes down (to the sea-bottom) to arouse his faculty and fulfill his functions of life—a gutta-percha boring and eating *teredo*, who has been waiting for his meal since the beginning of the world." This enemy of submarine cables has already made his appearance, as was briefly announced in a recent number of THE MONTHLY. It is a crustacean, less than a quarter of an inch in length, and known as *Limnoria terebrans*. "One breakfast which he may take," says Dr. J. H. Gladstone, "may cost more than the breakfast of any luxurious Roman epicure in ancient times, because he may destroy a whole cable, and it may take a year to repair the damage which he may do in a minute."

Hawkshaw on the Channel Tunnel.—In the course of the debate which followed the reading of a paper on the proposed tunnel between England and France, at the Bristol meeting of the British Association, Sir John Hawkshaw made a speech, in which he expressed his perfect confidence in the ultimate success of that great undertaking. "The question arises," said he, "as to the risk in tunneling through the chalk. Of course we cannot measure that risk with any certainty, but we are constantly in the habit of undertaking engineering work which sometimes involves an unknown amount of risk, and it becomes the business of the engineer to encounter these risks. Prof. Hébert seems to expect that the chalk, although it may be continuous, as we have ascertained it to be, all across the channel, may have such fissures in it that, in constructing the tunnel at the depth we propose to go, it is possible we may cut through the chalk into the green sand. Suppose that were so, it would not deter me from encountering this work. A great mistake is often made with reference to the percolation of water. Water, though it passes through sand, passes with very slow velocity. I have had to make deep excavations in sand fifty or sixty feet below the level of the sea, and though water comes rather rapidly at first, until it has drawn away a portion of the water which is in the sand adjacent to your work, yet, after that, it comes with extreme slowness. Therefore, I am not afraid of percolation of water in that sense. With regard to the percolation of water through the solid chalk, that is of no consequence; water passes so slowly through chalk, that it might continue to pass, and nobody would care about it. Of course there is a thing that might occur which would be serious. If you could imagine a clear, open fissure from the bottom of the sea to the tunnel, where water could pass, there is no doubt, with that enormous pressure, it would pass with very great velocity, and would be a very troublesome thing to encounter. I do not myself believe in there being any such fissure. That is almost the only difficulty which, I think, would hinder this tunnel. I do not mean to say that would stop it, but it is possible, if we met with a thing like that, we should have to have recourse to something else, which I have not yet devised, because I do not expect it."

Sanitary Condition of Watering-Places.—At the Baltimore meeting of the American Public Health Association, Prof. Henry Hartshorne read a report on the sanitary condition of our popular watering-places. The report points out the danger to health at such resorts from the contamination of drinking-water by soil saturated with sewage. To prevent this, one or both of two measures must be adopted, namely—1. To use for cooking and drinking either rain-water or water conveyed from a distant, uncontaminated source; or, 2. To protect the soil from contamination by the construction of impervious wells for receiving all impure matters. The former of these measures is always safest; for the latter to be carried out without injury to health requires close and constant supervision. The report finally expresses a desire that records of disease and mortuary statistics of the watering-places in the United States be collected at some central point

Geology at the Syracuse University.—The elementary instruction in geology at Syracuse University, which heretofore has been distributed through the first and second terms of the collegiate year, will be given this year during February and March, so as to occupy the attention of the students with this subject almost exclusively

during those two months. The plan is intended to accommodate the large number of persons of all ages who feel the desirableness of an outline acquaintance with geology, and who might be able to devote two months to the study, while their convenience does not permit them to take an entire geological course, or to keep the study in hand six months or a year. Simultaneously with the elementary course, two advanced courses will be set on foot during the months named; one of these courses will be Lithological, and the other Paleontological. Prof. Alexander Winchell will have the general direction of this special school of geology, with numerous assistants, among whom are Prof. James Hall, Prof. Burt G. Wilder, and Prof. Edward D. Cope. The school opens on Tuesday, January 25th.

The Value of Vivisection.—The question of vivisection was the subject of an address by Dr. William Rutherford, at the last meeting of the British Medical Association. Physiology, he observed, is an experimental science. Apart from experiments which are the result of artifice, disease and accident are constantly bringing about conditions which partake of the nature of experiments, and are sometimes of great physiological significance. Still, this teaching of disease and accident leads us but a short way, and the pursuit of physiological truth by their aid is often an uncertain, devious, and complicated method. Dr. Rutherford effectively contrasted the very imperfect and indirect theoretical method of physiological instruction in the past with that by demonstration and experiment in the present time. No one can doubt for a moment that the reasoning, critical faculties are truly educated where men are trained to see and examine for themselves the experimental evidence on which physiological knowledge rests. Dr. Rutherford holds that definite, critical knowledge of animal mechanism cannot be attained unless students be shown experiments on living animals.

Prolific Peaches.—At a meeting of the Academy of Natural Sciences of Philadelphia, Mr. Meehan exhibited some branches of peach, in which the young fruit were in twos and threes from one flower. They were from the Chinese double-flowering kind. He remarked that, as is well known, plants with double flowers are rarely fertile. Either the stamens are wholly changed to petals, or the less vital conditions which always accompany this floral state are unequal to the task of producing perfect pistils. Vitality, however, he observed, is more or less affected by external conditions, independently of the mere structure of organs, and this was well illustrated by the remarkable fertility of the peach last season. This abounding vitality had evidently extended to the double peaches, and had influenced the development of the female organs to an unusual extent. These facts have an interest in botanical classification. Lindley removed the cherry, plum, peach, and their allies from the *Rosaceæ*, chiefly because they had but a single free carpel, and grouped them as *Drupaceæ*. The production of two and three carpels in this case shows the true relation, and it might be of use to those interested in "theories of descent."

Stability of Chinese Civilization.—In accounting for the wonderful cohesion of the great Chinese Empire, the Prussian traveler Von Richthofen says that the causes of this phenomenon are manifold. First, the pitiless extermination of such tribes as the Man-tse. Then the complete fusion of uncultured races with the civilized Chinese, from which has resulted an homogeneous people, with one language, the same manners, and the same traditions. But above all stands the fact that Chinese civilization is indigenous. In Europe, civilization is the result of the efforts of several nations, and has been attained only at the cost of much strife and sacrifice, one people transmitting to another its hard-earned advantages. But in China civilization was developed in more orderly fashion, and is the product of the genius of a single people. The Chinese have very rarely come in contact with neighboring peoples, nor have they borrowed from the Hindoos any thing save Buddhism, and that has certainly been of no advantage to the nation. For 4,000 years they have faithfully preserved the religious and political principles set forth in the decrees of the Emperor Yan, and, though again and

again the edifice raised upon this firm foundation has tottered, it has been again set up on the same basis. These principles, which alone uphold the unity of this vast empire, stand to this day intact, nor does Von Richthofen perceive any evidences of senile weakness in the body politic; on the contrary, he thinks that in the future Chinese civilization will have a mighty development, without losing any of its native characteristics. The principles which governed its first establishment, and which are still influential in moulding it, are in fact perfectly in accordance with natural laws, being simply the application to the social and political state of the principles of the paternal authority and filial obedience. In China the authority of the father of a family is unlimited, the obedience of the son is absolute. The emperor, as the father of his subjects, the mandarins, his representatives, receive from the people a filial obedience, but at the same time the sovereign must conform himself to the holy maxims of Confucius. There may be cases of defection, rebellion; functionaries may yield to corruption, as has been the case of late years; but sooner or later order will be restored, and the mandates of the central power will be again respected to the outermost limits of the empire.

European Life in India.—The "Value of European Life in India" was the subject of a paper read at the last meeting of the British Association by Dr. F. J. Mouat. The author stated that within the present century the annual loss of European life in India had gradually and steadily decreased from about 60 per 1,000 to an average of 15 or 16. This decrement is still in progress. Among 24,500 British army officers in India, from 1861 to 1870, the death-rate from all causes was not quite 17 per 1,000. In the Madras Presidency, in the same period, among corresponding classes, the average rate was somewhat less; and, among carefully-selected European railway employés, the parliamentary returns show the mortality rate to be about 10 per 1,000. The author expressed the opinion that the Anglo-Saxon colonization of the plains of India is impossible; but that in the hill country a healthy, vigorous, European population could take root and flourish. On the whole, he regarded the present state of the question as most encouraging, and that the risks to life in India of persons who were sound in constitution, and reasonably prudent in their mode of life, are not much in excess of those incurred in more temperate climates.

Cost of a Small-Pox Epidemic.—At the recent meeting of the American Health Association a paper was read by Dr. Benjamin Lee, on the cost to the city of Philadelphia of the small-pox epidemic which existed there in the winter of 1871–'72. When the disease first appeared, no effective measures were taken to combat it. The public treasury could not bear the expense, it was said; besides, were any thoroughgoing action to be taken by the city authorities, traders from abroad would learn that the disease prevailed in the city, and would go to other markets. Dr. Lee's paper is intended to show that herein the authorities were "penny wise, pound foolish." The direct and the indirect losses caused to Philadelphia by that one visitation of small-pox amount to an enormous sum of money, a small fraction of which would have sufficed, if judiciously expended, to insure immunity from the disease. The losses as computed by Dr. Lee exceed $20,000,000.

NOTES.

THE article on "the Horseshoe Nebula in Sagittarius" in the number of THE POPULAR SCIENCE MONTHLY for January, 1876, contains two annoying errors which the editor desires to correct. In Fig. 2, page 271, the letters *W* and *E* and also the letters *N* and *S* are interchanged.

In Fig. 6, page 279, great injustice is done to M. Trouvelot's drawing, owing to the introduction by the engraver of two bright patches near *e* and *d*, and *c* and *h* (*see* figure). These should be as faint as the nebulosity near *g*.

THE cores of a pair of enormous ox-horns were discovered, some years since, in Adams County, Ohio, at the depth of about 18 feet below the surface of the ground. According to the *American Journal of Science* they measure nearly 6 feet from tip to tip, and are 22 inches in circumference. The original horns must have been of enormous size, as the core of the horns of the ox is about one-third of the entire length.

These horns are now in the Museum of the Cincinnati Society of Natural History.

It is an error to suppose that the lion is stronger than the tiger. Dr. Haughton has proved that the strength of the lion in the fore-limbs is only 69.9 per cent. of that of the tiger, and the strength of his hind-limbs only 65.9 per cent. Five men can easily hold down a lion, but it requires nine men to control a tiger.

In the course of his researches into the habits of insects, it was found by Lubbock that an ant, which has a large number of larvæ to carry from one place to another, goes and fetches several other ants to aid in the work, while, if there are only a small number of larvæ, only a few helpers are called in.

It is stated by Dr. George Maclean, of Princeton, in a communication to the editors of the *American Journal of Science*, that on one occasion, after some experiments with phosphuretted hydrogen, prepared from phosphorus and solution of potash, on retiring to bed, he found his body to be luminous with a glow like that of phosphorus exposed to the air. Some of the gas, escaping combustion, or the product of its burning, must have been absorbed into the system, and the phosphorus afterward separated at the surface have there undergone cremacausis.

Three instances of extraordinarily rapid growth of plants are recorded in the *Gardener's Chronicle*. First, a *Sequoia gigantea*, planted in 1855, in Loire-Inférieure, France, is now more than 72 feet high, and, about a yard from the ground, has a girth of 7 feet. In the same locality, a plant of *Bambusa mitis* threw up a stem of more than 22 feet in two months, while a *Yucca albospica* produced an inflorescence 8 feet high.

According to Dumas there are two distinct kinds of ferments: those which, like yeast, are capable of self-reproduction, and those which, like diastase and synaptase, are without this property. It has been observed by Muntz that ferments of the former class are neutralized by chloroform; not so those of the latter class.

Prof. S. P. Sharples, of Boston, has drawn up tables showing the range of difference between different specimens of pure milk as regards the amount of solid matter they contain. The highest percentage of solid matter is 19.68, the lowest 9.3.

It is stated in a French journal, *Le Charbon*, that experiments made at Bordeaux with cork, as a substance for developing illuminating gas, have led to such good results that it is proposed to establish a cork gas-house in that city. The waste of cork-cutting shops is distilled in close vessels, and the flame of the resulting gas is more intense and whiter than that of coal-gas. The blue portion of this flame is much less, and the density of the gas much greater than that of common illuminating gas.

It is stated by Galton that in England country boys, of fourteen years, average an inch and a quarter more in height, and seven pounds more in weight, than city boys of the same age, as shown by the examination of a large number of boys in country and city schools.

Dr. Robert Barnes, writing in the *Obstetrical Journal*, questions the propriety of admitting women to the practice of medicine. The reason he assigns is, that there exists a natural incompatibility between science and the female brain. The church and the law he considers to be the professions most congenial to the "somewhat arbitrary character of the female intellect." Clergymen and lawyers are, as a rule, the enemies of science, says Dr. Barnes, and in the women they find their most useful allies.

From observations made in Colorado by a member of the Academy of Natural Sciences, of Philadelphia, it would appear that grasshoppers can foresee, and provide, some time in advance, against certain changes in the weather. It happened that, while a party of persons were riding in a carriage, the question of the probability of rain was discussed, when suddenly the grasshoppers, which just before had filled the air, descended like a shower to the ground. In two or three minutes, not a grasshopper could be seen in the air, and very soon rain commenced to fall. Immediately after the rain had ceased, the insects took flight again, but in the course of half an hour, without any particular indication of rain, they suddenly plunged to the earth again. Again the rain began to fall. This process was repeated by the grasshoppers three times in one afternoon, and each descent was followed by rain.

Herr Marno, of Gordon's Nile Expedition, has reported to the Vienna Geographical Society the particulars of a journey made by him for a distance of 150 miles to the southwest of Lado. This brought him to the Makraka territory, the natives of which he says resemble the Niam-Niams, in respect of their diminutive stature, their lighter color, and their general habits.

In view of the recent barbarous exhibition at the Tombs, the *Scientific American* recommends the employment of electricity, as not only sure and instantaneous

in its action, but a painless means of killing the criminal.

DUMAS sums up as follows the results of numerous experiments made in order to test the efficacy of the sulpho-carbonate of potassium, in destroying the grape-phylloxera: In the first place, the phylloxera is destroyed wherever the solution of the salt or its vapor penetrates. Secondly, the vine itself suffers no injury. Occasionally, a very few living phylloxeræ are seen after treatment; but these come from other neighboring vines which have not been treated with the sulpho-carbonate, or have been hatched from eggs which have in some way been protected from the action of the salt.

DR. RUDOLF VON WILLEMOES-SUHM, naturalist attached to the Challenger expedition, died at sea on the passage from Hawaii to Tahiti, on September 13, 1875, aged twenty-eight years. He was a native of Schleswig-Holstein, and was educated at the Universities of Göttingen and Bonn. He early showed a very strong taste for natural history, and when only a boy published papers on the habits of European birds. After leaving Bonn he was appointed Privat-Docent in Zoölogy in the Munich University. He went to Italy in 1868, making zoölogical observations at Spezzia, and in 1872 visited the Faröe Islands. He then joined the Challenger expedition. He was a man of unusual acquirements and culture.

THE biennial prize of 20,000 francs has been awarded by the Institute of France to M. Paul Bert, for his discoveries on the effects of oxygen in the act of respiration. Some of the principal results of Bert's researches have been stated in the pages of the MONTHLY. According to the eminent physiologist, Claude Bernard, Bert's discoveries are "the most astounding that have been made since the discovery of oxygen by Priestley."

THE Royal Society of London has awarded to Mr. Crookes a "Royal Medal," for his various chemical and physical researches, more especially for his discovery of thallium, his investigation of its compounds, and determination of its atomic weight, and for his discovery of the repulsion referable to radiation.

AN interesting experiment made by G. Planté, and described by him to the Paris Academy of Sciences, may possibly explain the spiral form of many of the nebulæ. The two copper electrodes of a battery of 15 elements being immersed in water containing one-tenth of sulphuric acid, the pole of a magnet is brought near to the end of the positive electrode. Immediately the cloud of metallic particles, borne away from this electrode by the current, assumes in the liquid a gyratory, spiral motion, resembling in appearance a spiral nebula.

IT will be gratifying to our readers to learn that the preliminary operations of the expedition sent under the auspices of the Hydrographic Office, United States Navy, to determine telegraphically the relative longitudes of points in the West Indies, have been so far successful. Captain Green, U. S. N., assisted by the officers of the United States ship Gettysburg, and by Mr. Rock, civil assistant, has so arranged his programme that the two temporary observatories at Havana and Key West are in the same circuit, and that the signals made at either station are recorded *directly*, without the intervention of the observer at the second station, on his chronograph. It is to be presumed that an important element of uncertainty is thus eliminated. All the arrangements for the work are in good order, and Captain Green acknowledges the most cordial assistance from the officials of the Government and of the cable companies.

THE production of gum in fruit-trees, M. Prillieux regards as a disease, which he names *gummosis*. The alimentary substances in the interior tissues, instead of promoting the plant's growth, are diverted to the production of gum, and a portion of them accumulates about gummy centres, which seem to act as centres of irritation. The production of gum at the expense of nutritive matter has no limit short of the complete exhaustion of the plant. The best remedy is scarification. To cure the disease, the materials appropriated to forming gum must be restored to their normal destination. Hence, a more powerful attraction for them must be introduced than that of the gummy centres. Now, the wounds of the bark necessitate the production of new tissues, and, under this strong excitation, the reserve matters are employed in the formation of new cells, and cease to be attracted in the wrong direction.

AN instrument for the rapid examination of oils and textures by means of electricity has been invented by Prof. Palmieri. The instrument will—1. Show the quality of olive-oil; 2. Distinguish olive-oil from seed-oil; 3. Indicate whether olive-oil has been mixed with seed-oil; 4. Show the quality of seed-oils; 5. It will indicate the presence of cotton-fibres in silk and woolen textures.

IT is stated by Dr. Malherbe that sewing-silk is sometimes impregnated with acetate of lead, and that seamstresses are frequently poisoned by introducing such thread into the mouth.